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PUBLICATION OF THE MAPS OF TENKE AND MANONO (ZAIRE) FROM LANDSAT DATA

Musungayi Yampania

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16. Abstract

This project was undertaken in order to publish maps of Tenke and Manono from Landsat data.

The collection of cartographic data on Zaire up to the present time is based on aerial detection.

However, this becomes very expensive if repetitive coverage is required in such a large country as Zaire.

This constitutes a serious handicap for establishing most of the maps of the country.

The integration with the Landsat program, among the data collection systems, would amount to a substantial contribution to the improvement of cartography in general.

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FOREWARD

The study of this project was undertaken in order to publish maps of Tenke and Manono from Landsat data.

The collection of cartographic data on Zaire up to the present time is based on aerial detection. In effect, aircraft are particularly interesting because of flexibility in the selection of the best flight conditions, the best altitude, and time of day conditions.

However, this becomes very expensive if repetitive coverage is required in such a large country as Zaire.

This constitutes a serious handicap for establishing most of the maps of the country.

The integration with the Landsat program, among the data collection systems, would amount to a substantial contribution to the improvement of cartography in general.

PUBLICATION OF THE MAPS OF TENKE AND MANONO (ZAIRE) FROM LANDSAT DATA

Musungayi Yampania*

INTRODUCTION

We can define remote sensing as the science and art /1** of acquiring information about a material object from measurements made at a distance without physical contact with the object of interest.

These measurements are possible using special instruments of remote sensing which are capable of carrying out spectral and spatial measurements, and also time variations within an energy intensity field.

The collection of ins truments on Landsat 1, 2, and 3 consists of two detector systems:

(1) A multi-spectral sweep analyzer (MSS)

This a four-channel radiometer which sweeps the surface of the earth and records the intensity of the energy reflected by particular features and objects on the surface of the Earth. It operates simultaneously in four distinct frequency bands of the electromagnetic spectrum.

---

* Presidential Study Service, E.R.T.S. Division, B.P. 3092, Mo. Ngaliema, Kinshasa, Republic of Zaire.

** Numbers in margin indicate foreign pagination

-Band 4: extending from 0.5 to 0.6 μm (in the green area of the spectrum

-Band 5: extending from 0.6 to 0.7 μm(In the red area of the spectrum)

-Band 6: extending from 0.7 to 0.8 μm (in the near infrared of the spectrum)

-Band 7: extending from 0.8 to 1.1 μm (in the near infrared of the spectrum).

The space resolution is .79 m (see reference 8).

However, on Landsat 3, the MSS system operates with 5 bands, and the four first ones are identical to those of Landsat 1 and 2 (channels 4,5,6, and 7). The fifth one is sensitive to the thermal infrared range (from 10.4 to 12.6 μm), and it covers a ground area of 185 x 185 km per frame with a spatial resolution of 237 m (see reference 8). /2

(2) The RBV System (Return Beam Vidicon)

This camera system is used because of its geometric accuracy. In the Landsat 1 and 2 systems, the three television cameras simultaneously photograph the same part of the Earth's surface in the following three spectral bands:

band 1: from 0.475 to 0.575 μm (in the visible spectral range)

band 2: from 0.580 to 0.680 μm (in the visible spectral range)

band 3: from 0.690 to 0.830 μm (in the visible and close infrared range of the spectrum).

The RBV system of Landsat 3 also operates according to the same principle, but with two television cameras instead of 3, as in the case of Landsats 1 and 2. The two cameras each operate in the spectral range between 0.505 and 0.750 μm with a spatial resolution of 40 m. The RBV frame covers an area on the ground of 98 x 98 km. Thus four frames are required for covering a MSS frame.

CHARACTERISTICS OF THE LANDSAT SYSTEM

Synoptic view: A single frame covers a very large area (3.4000 km^2) and makes it possible to observe the location and the area of a determined category of resources over a wide area.

Repetitive character of observation: The regular passage of a satellite above the same zone every 18 days (or every nine days if there are two satellites in orbit simultaneously) makes it possible to observe the evolution of phenomena such as the following: changes in watercourses, the development or the /3 degradation of vegetation...

Uniformity in time: By over-flying each zone by the Landsat at approximately the same time of day ($\pm$ 9 hours 30 minutes) on the equator, it is possible to guarantee a large uniformity of illumination to successive images. This regularity of the solar incidence angle constitutes an additional accurate element for surveillance functions such as: study of erosion, study of evolution of swamp areas, etc.

Uniformity of views of an ensemble: Possibility of establishing image mosaics which cover wide areas with exceptional regularity and precision. /4

PURPOSE OF PERIODIC REVISION OF A MAP

The economic development of most of the non-industrialized countries essentially depends on their natural resources. However, most of these nations do not have sufficient knowledge about the nature, quantity, and location of their resources so that they can efficiently develop them to the benefit of their population.

When defining the term of natural resources, we can include everything which has a value for humans in their physical environment, such as: ground, water, vegetation, energy sources...

These resources themselves are closely related. Modifications of one of them can affect others.

There are renewable resources and others which are not renewable, but neither is unlimited. Because of their relative rarity, their utilization and their conservation imply a rational planning process. In order to do this efficiently, a country must know its resources and where they are located, and it must have a detailed knowledge about its global physical environment.

The state of the earth, cultivations, forests, and pasture lands, the behaviour of watercourses, and the ways in which the land is used are subjected to continuous fluctuations and require surveillance. Periodicity is required in order to develop information which can be effectively utilized. /5

It is within this framework that this project is effective. The map of Tenke was made in 1929 , and that of Manono was made in 1974 with photographic coverage from 1952. Many things have changed since they were published. They no longer reflect the real physionomy of the ground, and it must be defined in order to be utiliized.

The last aerial coverage work in Zaire was in 1952, and only covered a small part of the country. There are other regions which have never been measured up to the present.

The country is very large for an aircraft to carry out the cartographic work.

Since 1972, the entire country of Zaire has been photographed by Landsat 1, 2, and 3 (see Figure 1). The data are stored by EROS (this is an Interior Department of the U.S.), and can be obtained in various forms:

- reels of CCT or microfilm
- tracings on paper in black and white, or in composite color tracings at the following scales: 1:1000.000; 1:500.000; 1:250.000.
- transparencies on a scale of 1:1000.000 (18.5 x 18.5 cm).
- films: 4 bands (4,5,6,7) of 55 x 55 mm. /7

INTERPRETATION OF IMAGES OF TENKE AND MANONO

The Landsat image is a document which condenses a large mass of information of a wide variety. These data can be applied in agriculture, geology, hydrology, cartography, etc.

Before an analysis, it is important to define the requirements in relationship to the spatial resolution of the image.

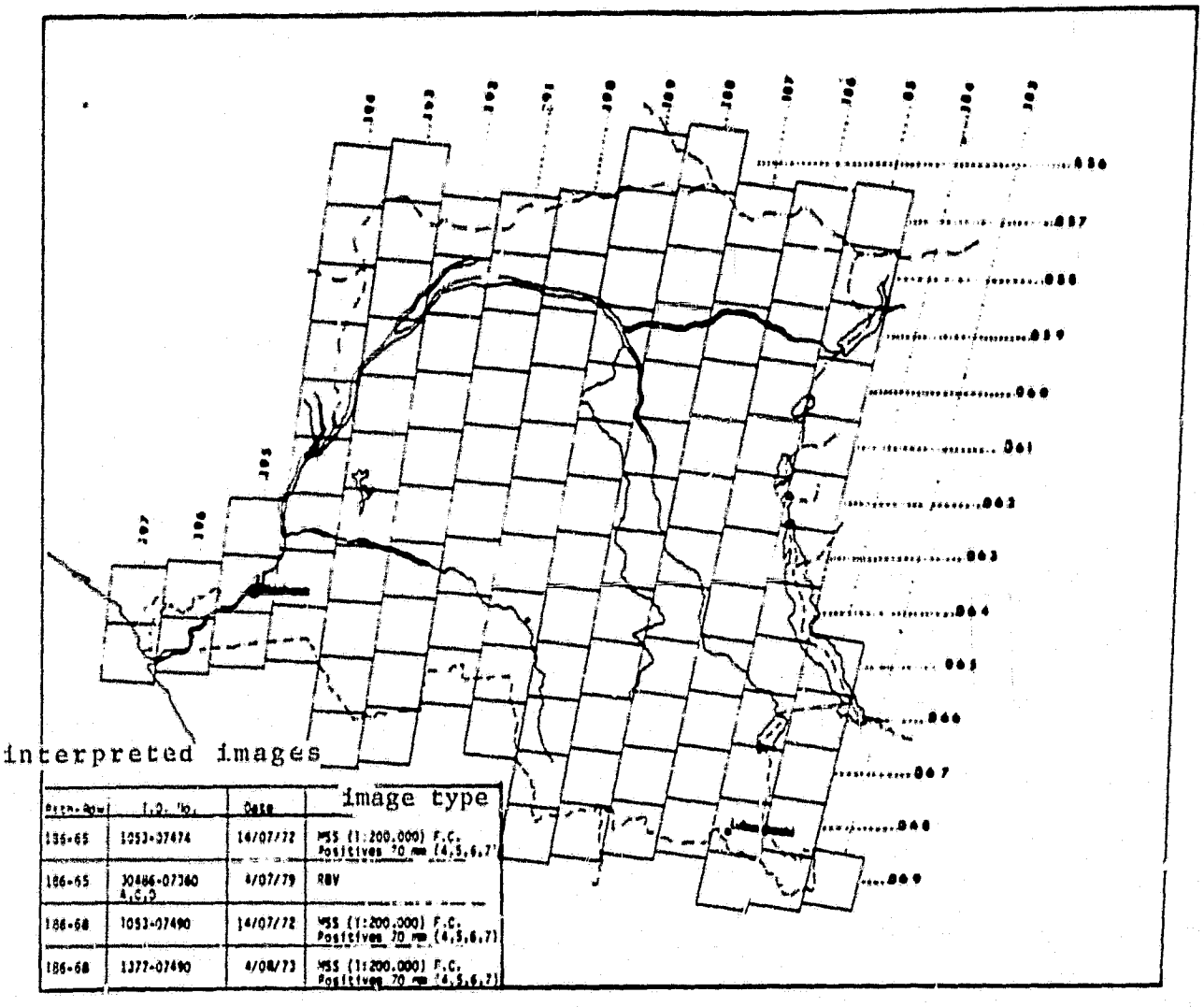
In this project, the selected elements are:

- built up areas (large agglomerations)
- mineral prospecting zones
- road networks
- vegetation
- watercourses
- lakes

Various methods can be used in order to extract this information:

- Direct interpretation of the images with increased contrast, which use more expensive optical equipment

- Direct interpretation of increased contrast images using numerical procedures, and using equipment mentioned above



Path-Row	I.D. No.	Date	image type
186-65	1053-07474	14/07/72	MSS (1:200.000) F.C. Positives 70 mm (4,5,6,7)
186-65	30486-07360 4,5,7	4/07/79	RBV
186-68	1053-07490	14/07/72	MSS (1:200.000) F.C. Positives 70 mm (4,5,6,7)
186-68	1377-07490	4/08/73	MSS (1:200.000) F.C. Positives 70 mm (4,5,6,7)

Figure 1. Index of Landsat images for Zaire

- Numerical analysis of the CCT on an interactive terminal in order to obtain the desired calculated product, which will be subjected to an interpretation and human analysis

- Visual interpretation which uses simple instruments which are cheap /8

As can be found, the three first methods are very expensive, and large sums are required to implement them.

Visual interpretation was used in this project, and is a simple and cheap procedure. It uses photo-interpretation techniques which are familiar to various specialists in earth resources.

In order to obtain the most information possible, the following additional methods are used:

(a) Interpretation using diazo techniques

This is a simple procedure which consists of converting a black and white film into color images with a minimum of photographic material. Three MSS products (4,5,7) on wires and three transparent base diazo in the desired colors are sufficient to obtain standard transparencies and false color transparencies in which the gray tones are represented by colored tints.

(b) Interpretation with the color additive viewer

This is a procedure which makes it possible to increase the contrast by varying the light intensity. Four colored filters placed in the instrument produce four different lights: white, green, blue, and red. Thus one can examine the usual spectral bands of a given frame through monochromatic filters with different intensities. With this procedure, the selected characteristics of the surface can be detected and reported with more efficiency.

(A) Frame of Manono /9

The Manono zone is a square area between 7° and 8° south, 27° and 28° east. It is included in frame MSS No. 1053-07474 of September 14 1972 (see Figure No. 2), and includes four RBV images (A,B,C,D), No. 30486-07360 of July 4 1979.

The data on Manono were extracted from the RBV mosaic which included only the three frames A, C, and D, because frame B was not available (see Figure 3).

The spatial resolution of RBV is 40 meters, which allowed us easily to detect agricultural activity and even the boundaries of certain plantations in the center and to the south of Manono.

The road network appears in white lines. Several large axes are visible, such as the following: the road which follows the Zaire river to the west, and which passes along the Bumbuzi river toward the center. We can also see several features in the south.

The mosaic shows houses with white roofs. The road network is often considered as an element which serves to identify inhabited zones. We can also use data on existing maps to show the following principle: landscapes having the same characteristics have related spectral signatures; 27 details were found to be cities.

As far as drainage and vegetation are concerned, it was found that RBV provides less information than MSS. This is due to the fact that the RBV system only operates in one panochromatic track (0.580 to 6.80 µm). The information on drainage and vegetation was completed by the interpretation of the MSS color composite (see Figure 2) performed by the combination of the three bands 4, 5, and 7. /12

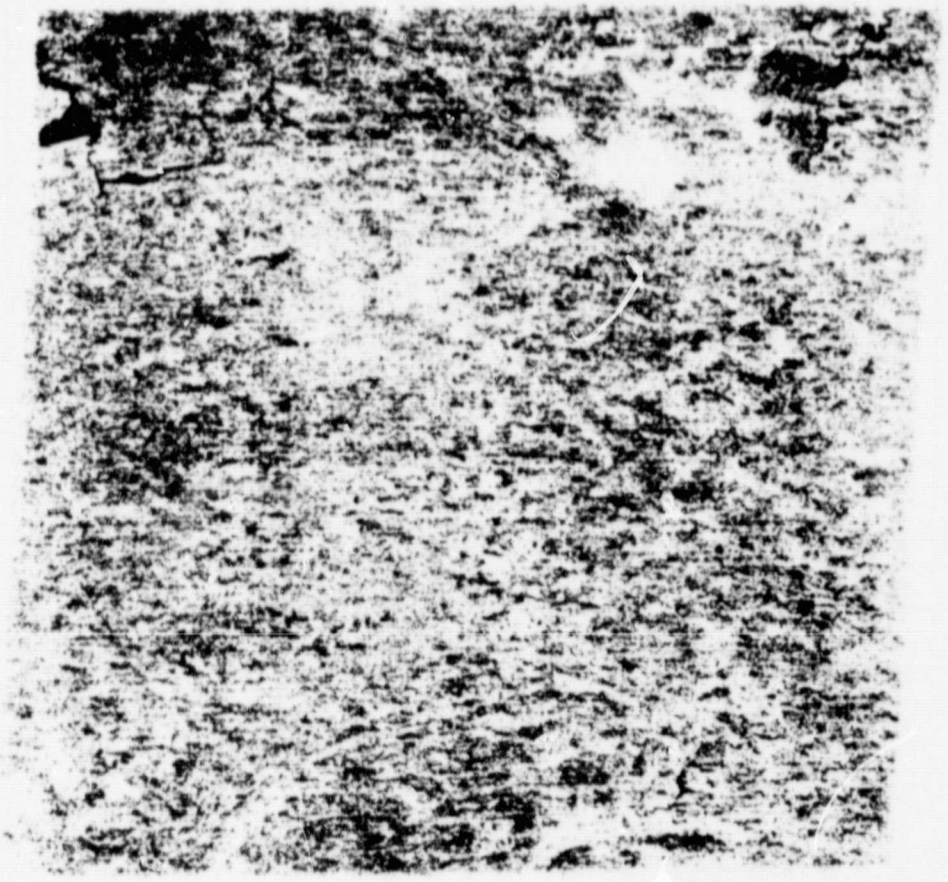


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Figure 2. Band 5 of Manono, frame NSS No. 1053-07474 of September 14, 1972. (The original frame is a false color composite).

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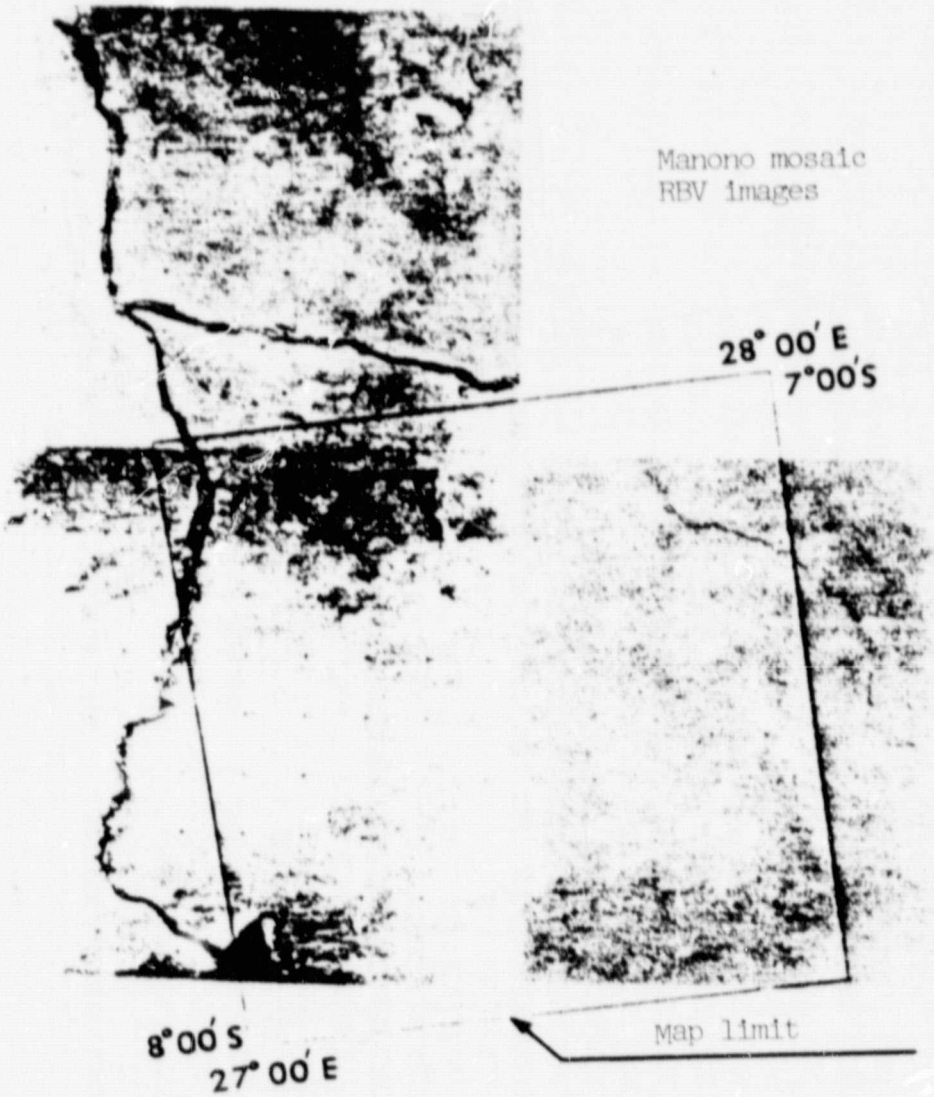

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Figure 3. Manono mosaic performed with frames RBV (A,C,D) No. 30486-07360 of July 4, 1979

This technique is useful to augment the contrast between the various details. The watercourses and the lakes appear in black. The vegetation in the various red tones appears more dense in the south, and to the northeast of Manono.

The image shows the alluvial sand in rose around the Kabamba and Mutupeke lakes, between the meanders of the Zaire river and those of the Lukuse river in the center.

The cartography of Manono, taken from Landsat data, is shown in plate 1 (see end of the report). It is obtained by the combination of the results from various procedures used in this study:

- interpretation of the RBV mosaic
- interpretation of the MSS color composite
- interpretation by the diazo techniques
- interpretation on the "color additive viewer"

(B) Tenke frame

/13

The Tenke region is a square between 11° and 12° south; 26° and 27° east. It is entirely included in the MSS No. 1377-07490 frame of August 4 1973 (Figure 4). The data on Tenke are from this color composite. The comparative analysis with a second MSS composite No. 1053-07490 of September 4 1972 provided the data on Tenke.

These composites were each taken from the three bands 4, 5, and 7 (70 m/m black and white negatives) and enlarged to a scale of 1:200,000 in the photographic laboratory of the Remote Sensing Institute (S.D.).

This procedure makes the image ready for interpretation. In effect, the use of multiple spectral bands increases the possibility for identifying or classifying characteristic elements on the ground.

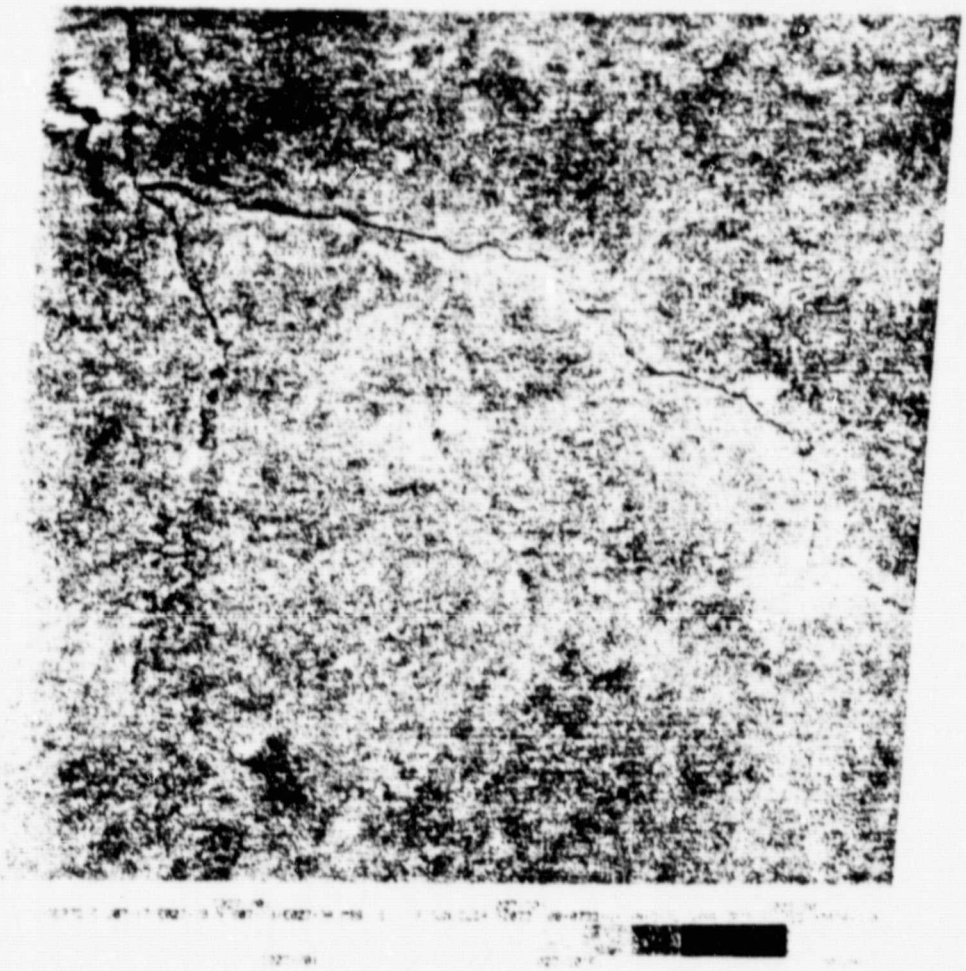

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Figure 4. Band 5 of Tenke, frame MSS No. 1377-07490 of August 4 1973. (The original frame is a false color composite).

Because of the exclusive capacity of the band 7 (0.8 to 3) to make boundaries between water and ground visible, the image (Figure 5) shows the drainage with very good contrast.

We can see the Lufira river in the eastern part of Tenke, which goes to the north and collects almost all of the water from the small rivers of this region before emptying into the Lufira lake. It can be seen that the watercourses in the western part of Tenke flow in the western direction.

As for band 5, it is used to detect the outline of roads, details on the development of urban and industrial zones, and the situation on the vegetation and the topography of the land. As far as this information is concerned, it was found that the color MSS composite is less efficient when one wishes to obtain data about roads. Over the entire Tenke road network, only /15 a few sections were detected in the northern part.

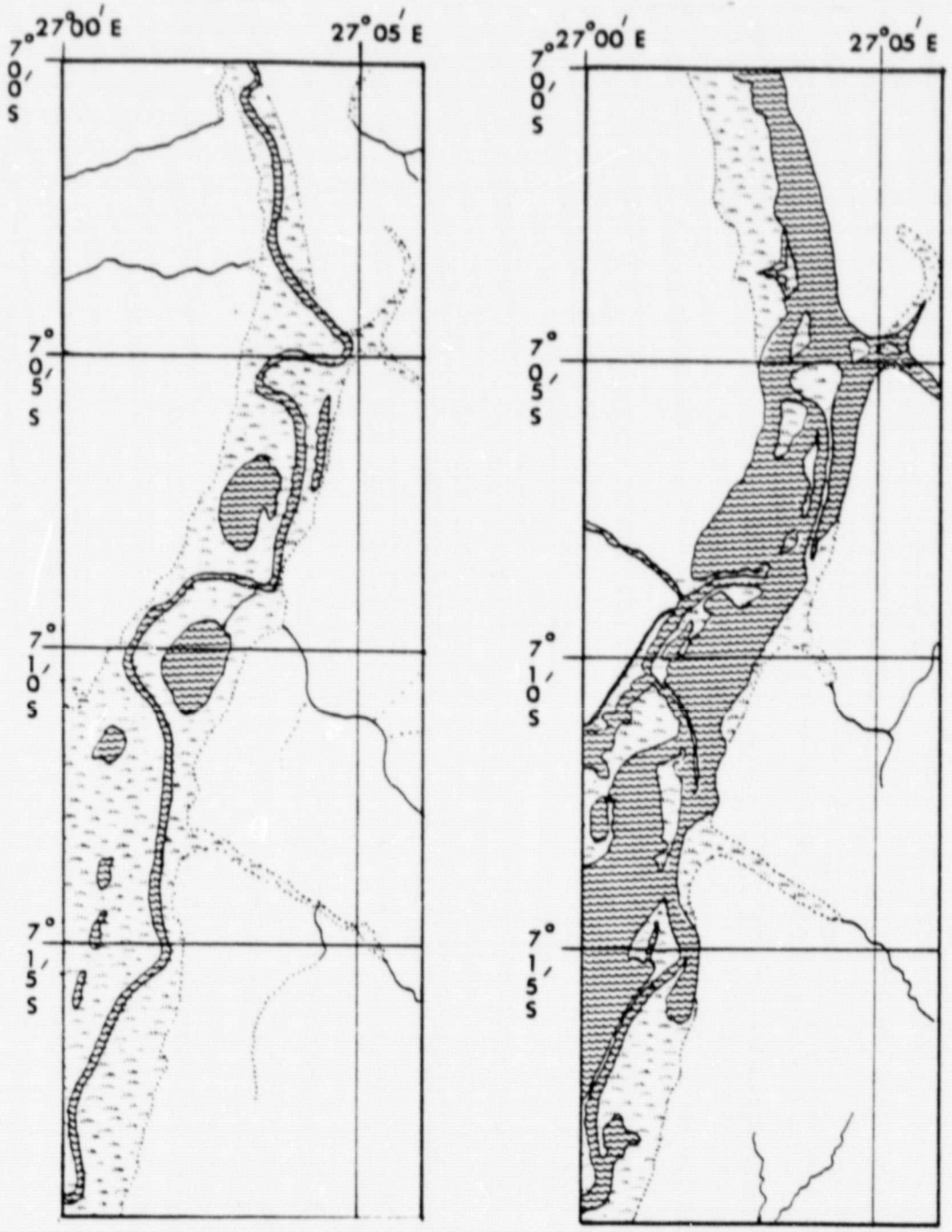
As for the urban and industrial zones which are shown in white, information is given on 17 details within the image.

The color composite also shows the mountain areas and the foldings in the rock, especially in the central and northern part of Tenke. The vegetation appears in various tones of red. It is shown in bright red on montains and can be classified as a forest.

The cartograph of Tenke, taken from the interpretation of two MSS images is shown on plate No. 2, folded and given in the final part of this report.

DESCRIPTION OF THE TENKE AND MANONO MAPS

Using the cutting cartographic system adopted by the



Scale 1:200,000

Scale:1:200,000

Lake, watercourse

Swamp

Figure 5,a is the representation of the Zaire river on the map of the Zaire Geographic Institute established from aerial photographs of 1952. Figure 5,b represents the same part of the river using RBV mosaic, Frame No. 30486-07360, of July 4, 1979

Zaire Geographic Institute, the Tenke and Manono maps are sheets covering one degree each.

The two zones appear in the region of Shaba (Zaire):

(1) Tenke sheet

The Tenke sheet (1:200,000) was published by the Katanga Special Committee (presently Shaba) according to work by its Geographic and Geologic Division carried out between 1924 and 1925, and additional measurements made in 1929.

The triangulation work was supported by the border chain established by the Katanga-Rhodesia Boundary Commission (1911-1914). When making the map, we took into account the topographic measurements carried out by this commission over a band five kilometers north of the boundary.

(2) Manono sheet

The Manono sheet (1:200,000) was made and printed by the Geographic Institute using photographic coverage carried out by this agency in 1952.

Triangulation and the ground work were carried out by the Geographic and Geological Division of the Katanga Special Committee.*

COMPARISON BETWEEN LANDSAT DATA AND CARTOGRAPHIC DATA

1. Tenke (see Plate No. 5, folded and shown at the end of this report).

After comparison, we found that the map and the image did not perfectly agree. Several hypotheses can be made on this point: either the color composite was not geometrically

*The maps of Tenke and Manono are folded and given at the end of this report. All of the names of the rivers, cities were not used in these maps.

corrected, or there are errors in the enlargment of the data for the terrain because of the fact that the map was made using an itinerary.

On the other hand, the disagreements which Figure 9 shows when one considers details alone can be considered as changes which occur between the date of the map (1929) and the date of the image (1973).

In the case of the watercourses, we can note:
- the rivers have disappeared entirely, or partially
- the rivers whose beds have become longer than before
- new rivers which did not exist on the map
- or rivers which changed the flow of their beds

As for the built over zones, of 17 details assumed to be villages or mining sites, 8 are not seen on the map. Are these new cities? Or are they new mining sites? These are questions which will be treated in the second phase of this study, the purpose of which will be to verify real features in the terrain.

The comparative analysis also showed that the roads on the image were not found on the map. As for the vegetation, this is a new element which has been added to the Landsat data.

2. Manono (see plate No. 6, folded and found at the end of this report)

Plate No. 6 shows the comparison between the map and the RBV mosaic of Manono. The map was made according to regular restitution. In a general manner, the details of the two documents correspond quite well.

We have the following changes:

In the case of drainage, the large changes found are shown in Figures 5, 6, and 7.

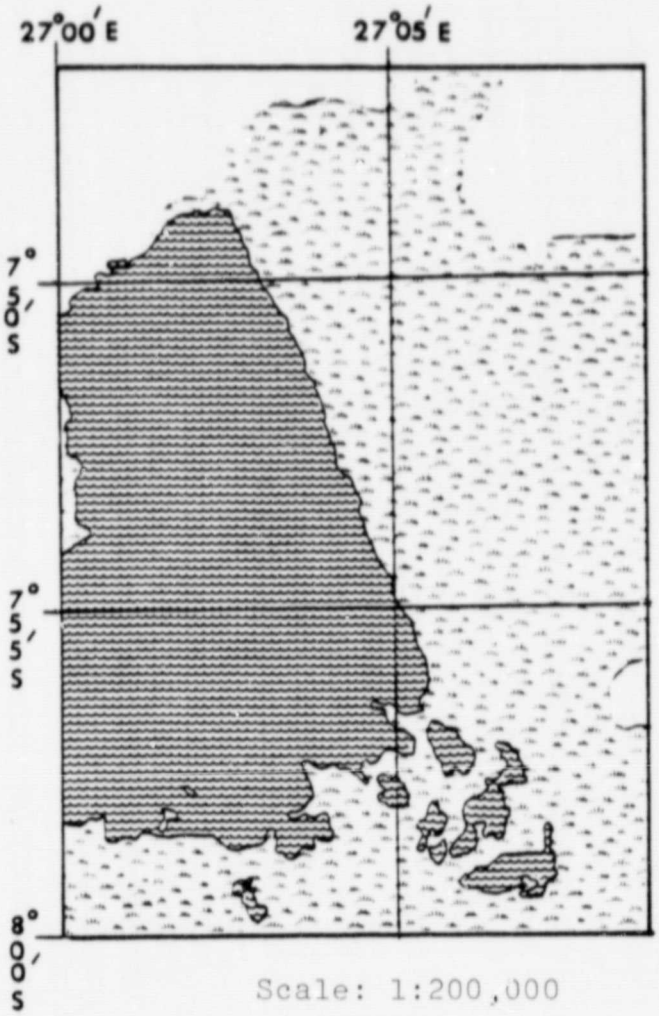


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Fig. 6-a

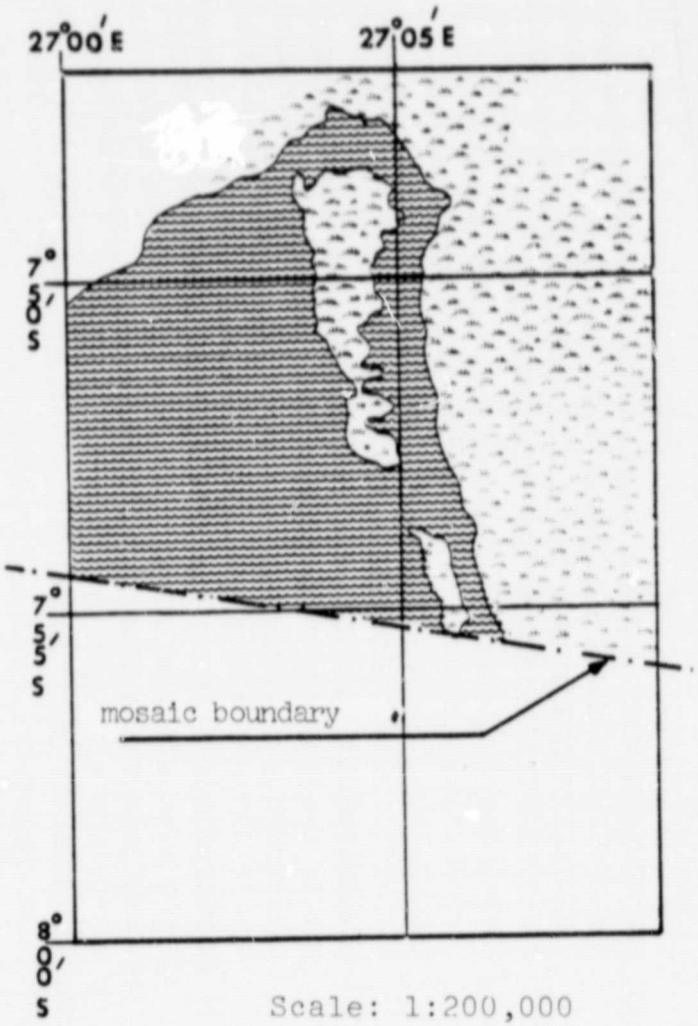

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Fig. 6-b

Lake, watercourse

Swamp

Figure 6. Figure 6,a represents the Kabamba lake on the map of the Zaire Geographic Institute established from aerial photographs of 1952. Figure 6,b is the cartograph of the same lake taken from the RBV mosaic, frame No. 30486-07360 of July 4, 1979.

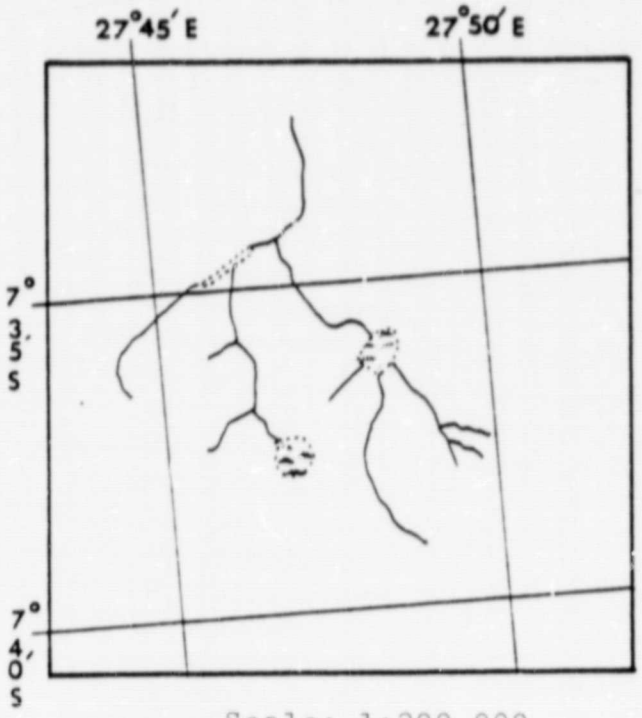

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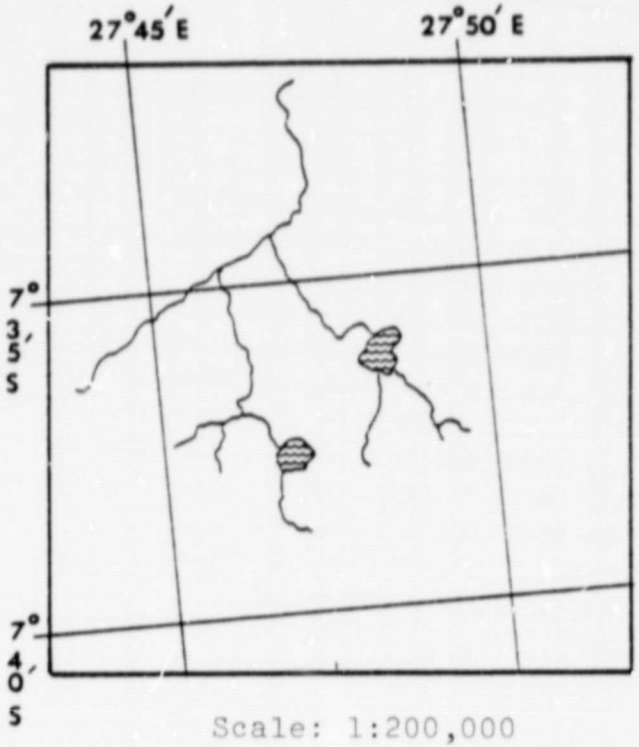
Fig. 7-a



Scale: 1:200,000

Fig 7-b

Lake, watercourse

Swamp

Figure 7. Figure 7, a shows the swamp areas on the map of the Zaire Geographic Institute established from 1952 aerial photographs. Figure 7, b shows the same swamp areas which became lakes on the RBV mosaic, frame No. 30486-07360 of July 4, 1979.

Figure 5, a shows the Zire river with lakes located between meanders. This information is taken from the map of the Zaire Geographic Institute, developed from aerial photos of 1952. Figure 5, b is the cartograph of the same part of the river, according to the RBV mosaic, frame No. 30486-07360

of July 4 1979. In this figure, the waters of the lakes and the Zaire river are merged, and the river appears larger on the image than it is on the map.

Figure 6,a is the representation of the Kabamba lake on the map. Figure 6,b shows the same lake as found on the RBV mosaic. The finding is: the lake is larger on the image than it is on the map.

One could easily conclude that the RBV image was taken at the time there was flooding of Kabamba lake and Zaire river. However, one thing is certain: this information was recorded by the satellite during the dry season. In the case where /21 this situation is really the effect of flooding, we could assume that the rainy season, which preceded the period during which the photography took place, was abnormally long and was characterized by strong rains during the latter months.

On the other hand, the converse situation is found for Bowe lake to the north of Kabamba lake. This lake, shown on the map and visible in the MSS frame of September 14 1972, is not recorded in frame RBV of July 4 1979.

This is a temporary change: in this case, the lake simply disappeared because of the dry season, and could reappear during the rainy season.

This is a definite change: considering the fact that this lake did not benefit from the flooding which occurred in this part of the region, we can assume that it has disappeared forever. This hypothesis could be of interest for the revision of the map.

The remaining question is to know the more or less constant boundaries of all the details. This requires repeated observations on their behaviour in different seasons. /22

The changes are also found for the two swamp zones located on the map to the east of Manono. These details are the lakes on the mosaic (Figure 7), and according to information from the Cartographic Agency of Defense, of the U.S.A., these lakes are called the following: Funze lake and Kafuzafunze lake.

The swamp areas primarily developed around Kabamba lake and to the southwest of Manono. The drainage has remained more or less stable. The lines shown with dots in Plate No. 6 indicate the change of certain rivers which were known because of the course of their beds.

As for the built-over zones, 17 of 21 details shown on the mosaic correspond to the old towns of Manono shown on the map. The 4 remaining ones have been retained in order to be verified on the terrain.

The road network did not change, considering the few roadway axes which can be found on the mosaic.

CONCLUSION

The uniformity of the views of an extended region, geometric and radiometric orthogonality, the remarkable definition of certain natural characteristics, and the capacity to be transferred to a cartographic finished product in quasi-real time are unique characteristics. All of these characteristics make up the Landsat image. a valuable tool in cartography.

The Landsat data can be used, not only to monitor dynamic phenomena because its repetitive nature, but can also be used to plan an aircraft over-flight project for particular observations which could be used to revise maps, or for a detailed study.

This reduces the time and money devoted to research on ground studies or a systematic aircraft observation of a region.

The final stage of this study will be a terrain visit. It will have the following purpose: verification of the hypotheses and toponymy of new elements.

Whether a study is based on the results of aircraft remote sensing or remote sensing from space, the data obtained will not be of much importance unless terrain verification is performed. Thus it is necessary to consider the maps resulting from the first stage as incomplete. The definite documents can be established after terrain visits have been performed.

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FOLDOUT FRAME

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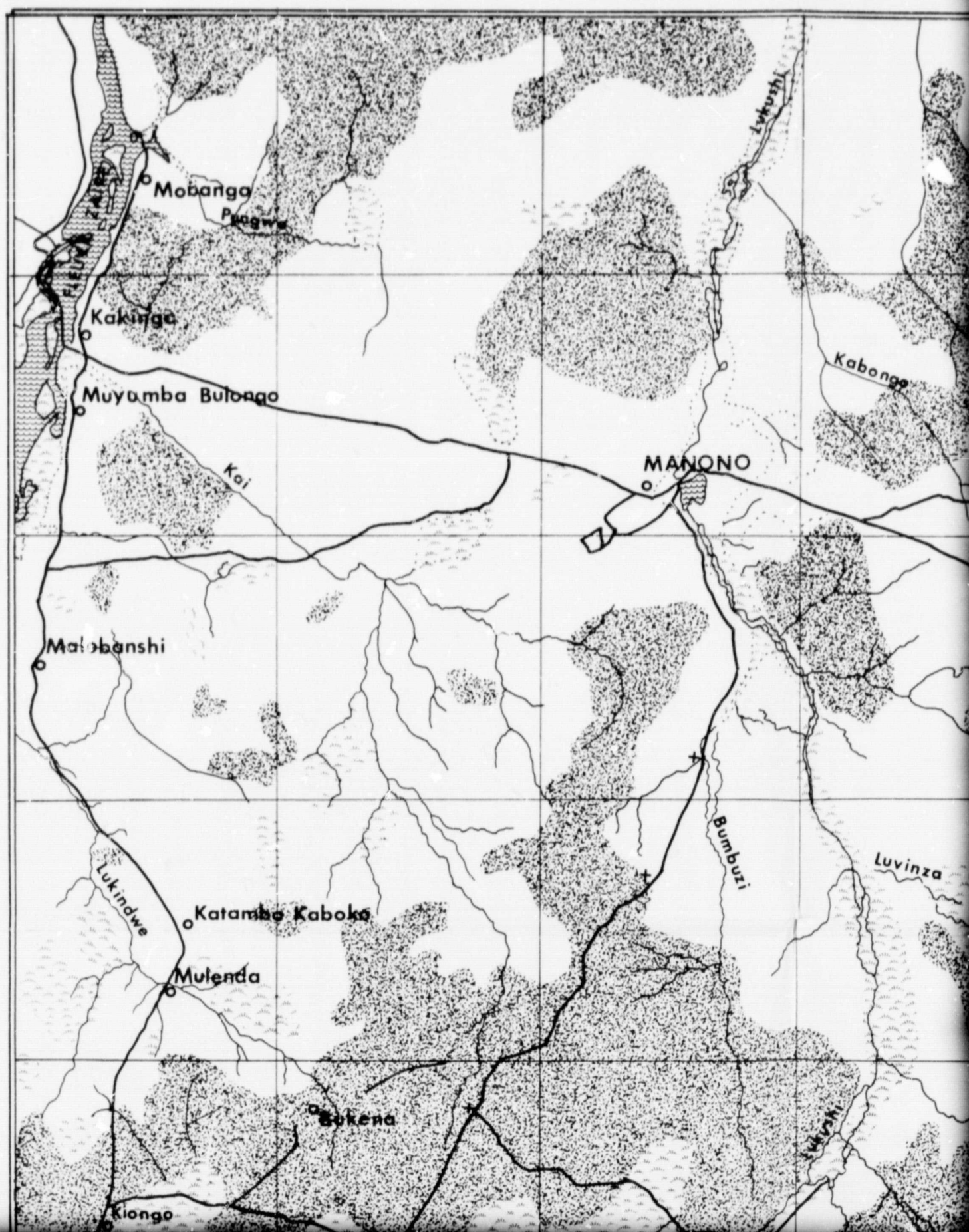
PLANCHE Nº 1 : MANONO

27° 00′

7° 00′

30′

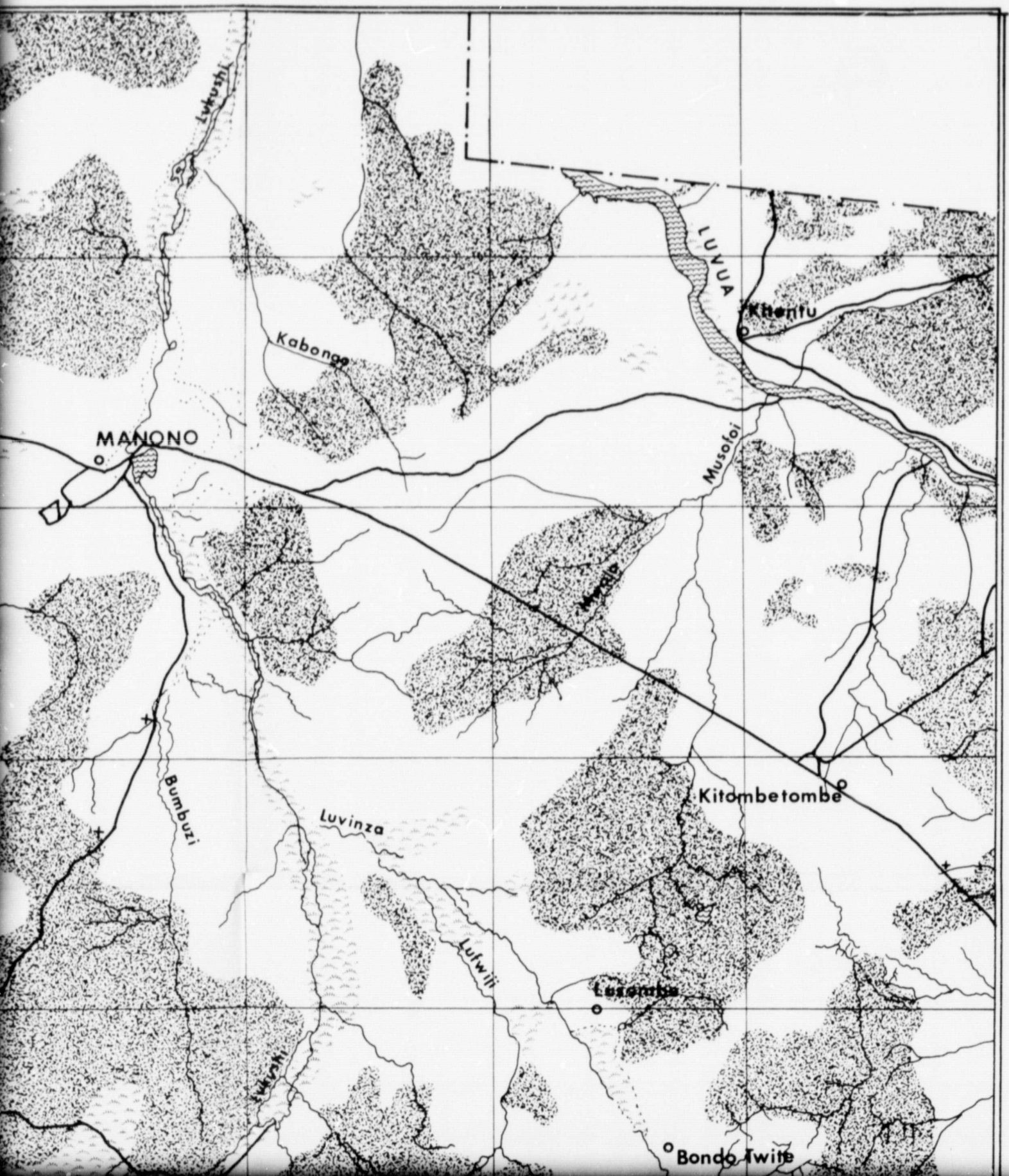


FOLDOUT FRAME 2

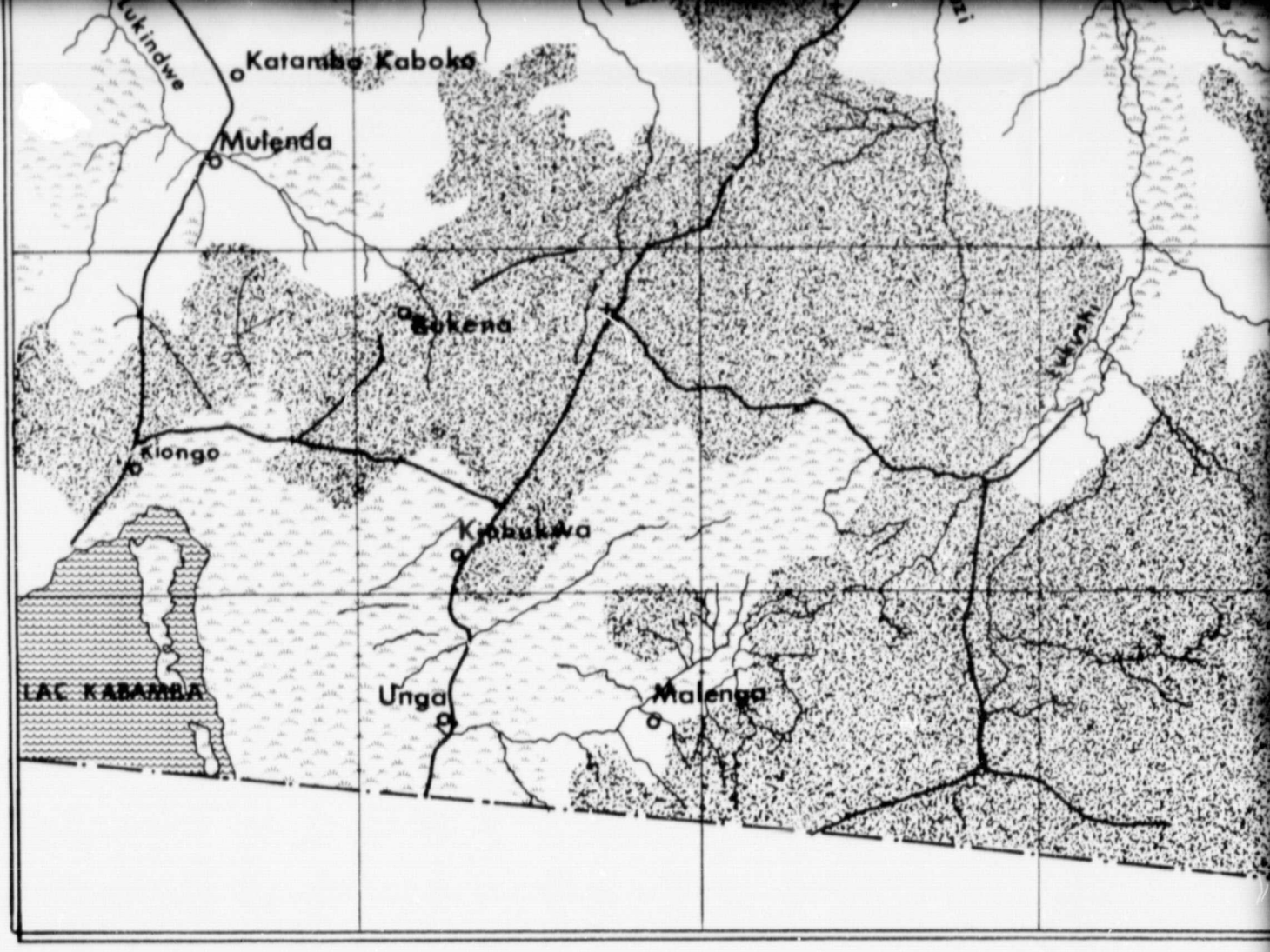
ANCHE Nº 1 : MANONO

28° 00′

7° 00



30



8° 00′

27° 00′

30′

0 5 10 15

Legend

- Lake, large watercourse
- River
- Swamp
- Vegetation
- Road
- City found on the old map
- New city not on the map
- Mosaic limit

This is the interpretation of the region sho

FOLDOUT FRAME 3

Plate No. 1 illustrates the richness of details wh
from Landsat images. Its ground definition allow
objects with an average dimension of 80 meters (MS
(RBV image) and sometimes less than these data bec
contrast with its environment. The corresponding
makes it possible to outline the countours of the
vegetation, swamp areas, inhabited areas, and road
sufficient contrast in the southwest part for the
drainage was not shown with the same density of ir

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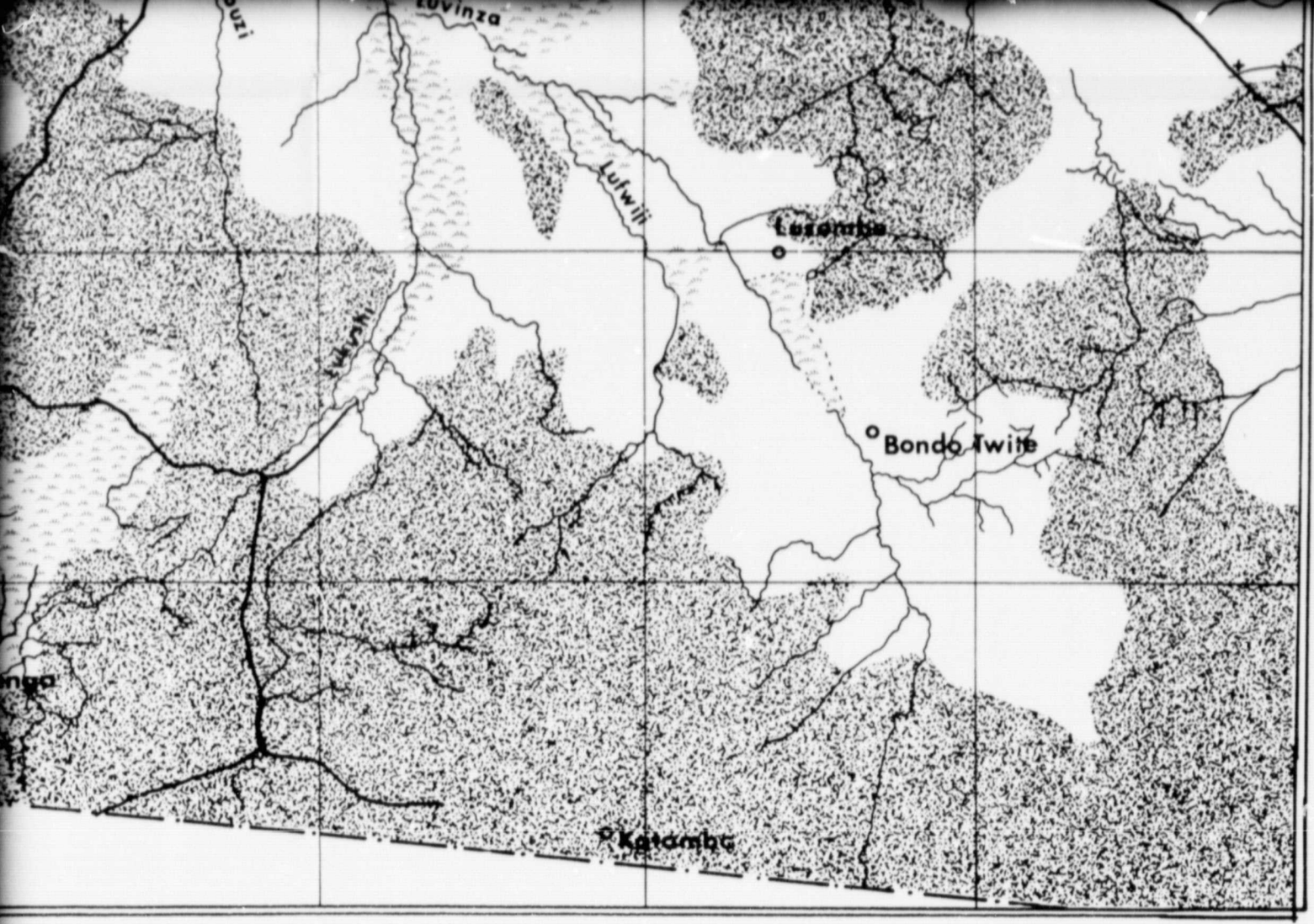


y found on the old map

city not on the map

aic limit

Cartograph taken from a composite mosaic made of 3 RBV frames (A,D,C) No. 30486-0760 of 4/07/79. Performed by Musungayi Yampania at the Brookings Remote Sensing Institute (U.S.A.)

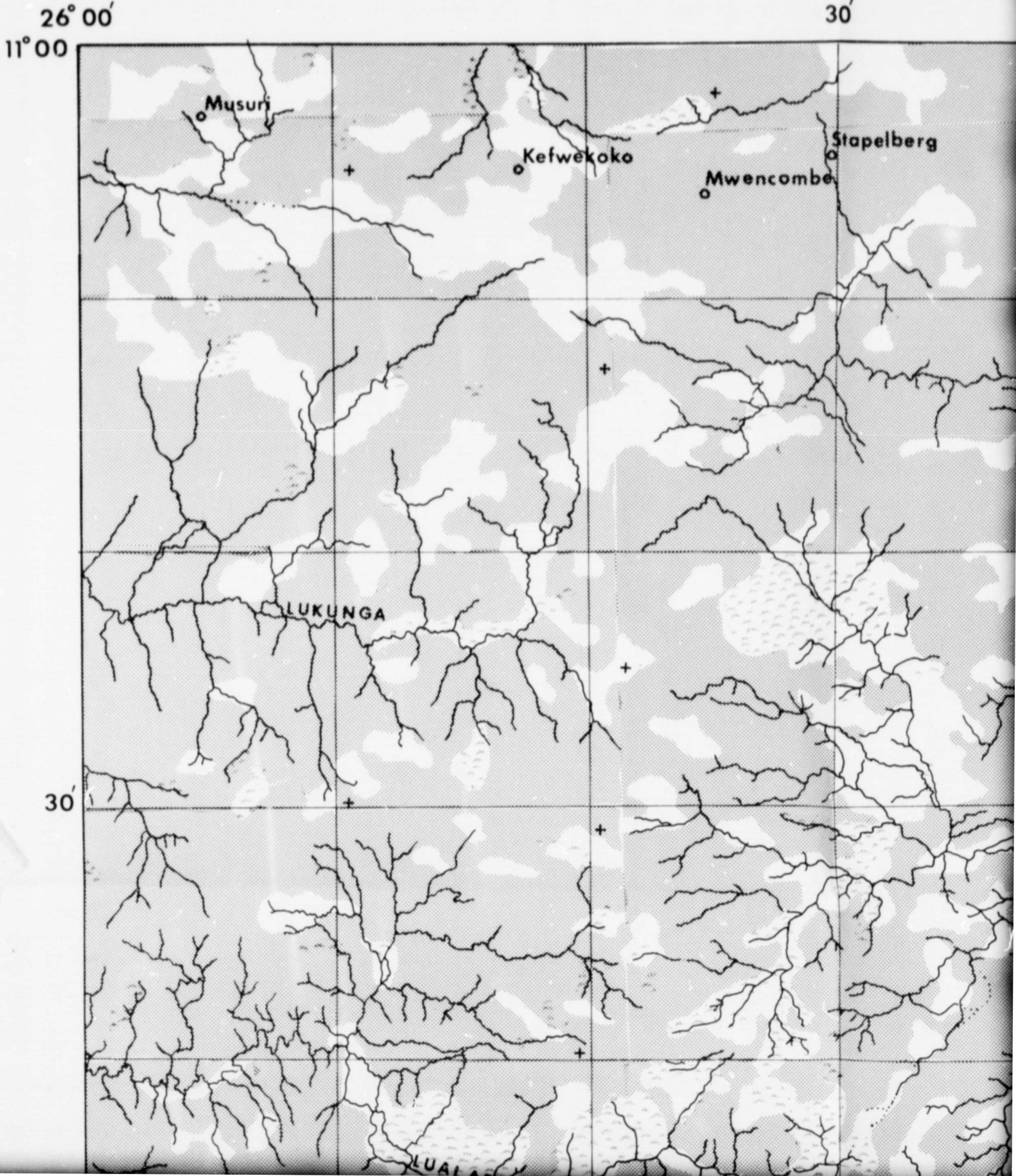
he interpretation of the region shown on Plate No. 4

FOLDOUT FRAME 4

ustrates the richness of details which can be obtained
ages. Its ground definition allows one to discern
average dimension of 80 meters (MSS image) or 40 m
sometimes less than these data because of the large
ts environment. The corresponding frame for this plate
le to outline the countours of the lakes, watercourses
mp areas, inhabited areas, and roads. Because of in-
rast in the southwest part for the small details, the
t shown with the same density of information as on the map.

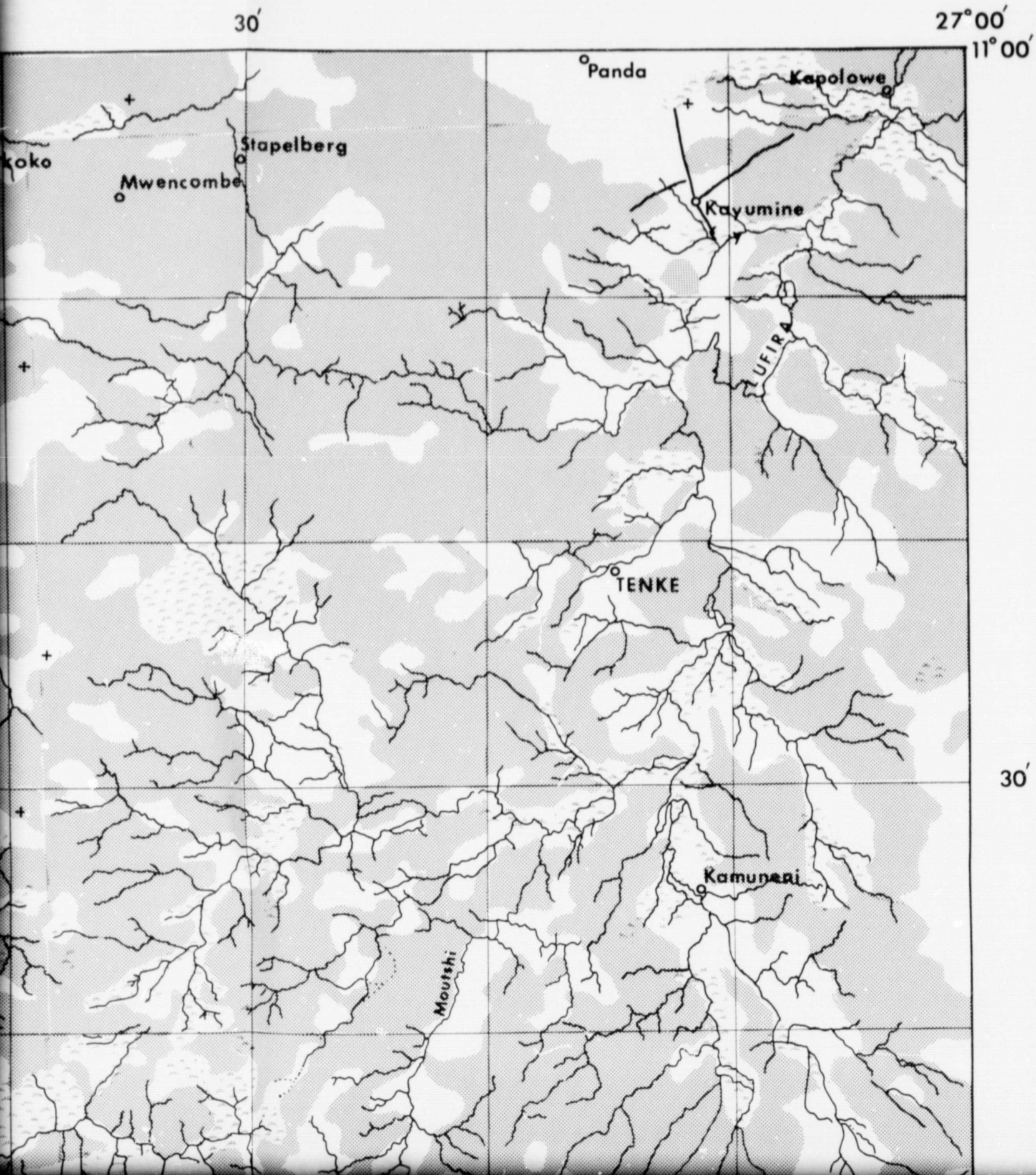
FOLDOUT FRAME

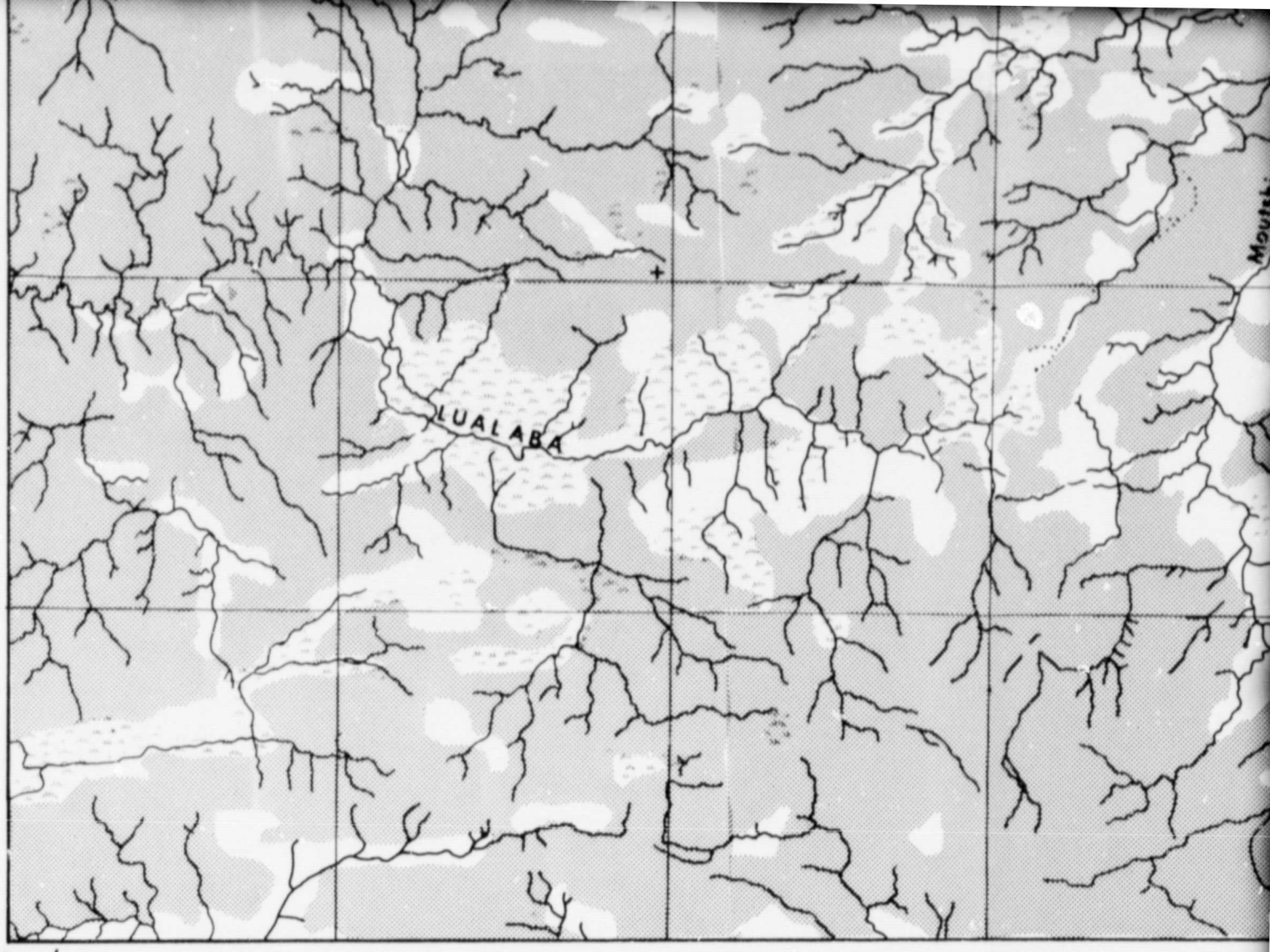
Plate No. 2 : **TENKE**



FOLDOUT FRAME 2

Plate No. 2 : **TENKE**





Legend

River

Swamp

Vegetation

Road

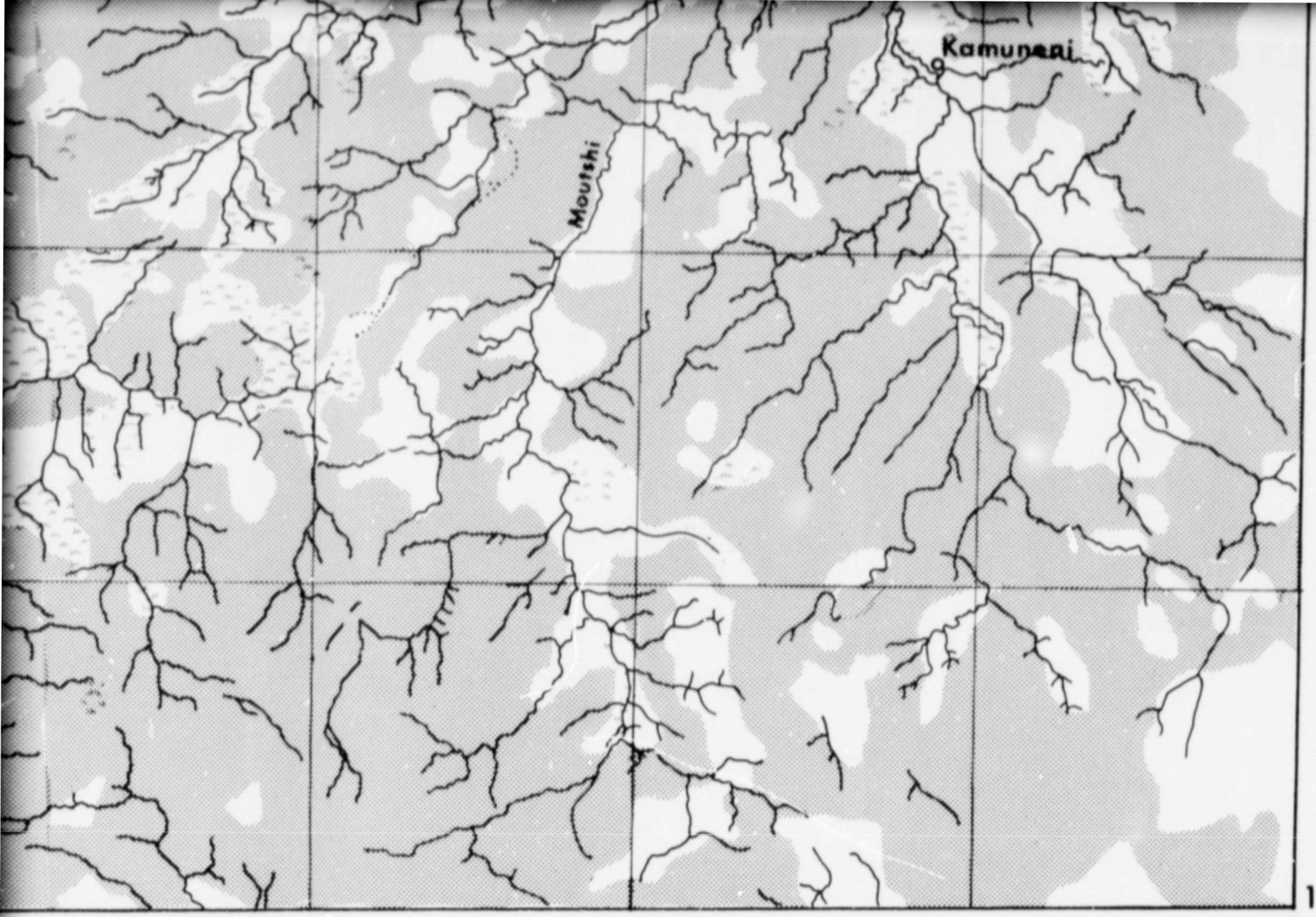
City found on the old map

New city not on the map

This is the interpretation of the region shown

Plate No. 2 shows the richness of details which can
MSS images. Its ground definition makes it possible
having an average dimension of 80 meters and sometim
the large contrast with its environment. The frame
plate made it possible to trace the vegetation conto
inhabited areas, watercourses, and several traces of
Because there was not sufficient contrast for determ
details, the image did not give as much information

FOLDOUT FRAME 3



he old map

n the map

Cartograph taken from a color composite, frame MSS No. 1377-07490 of August 4, 1973, taken by Musungayi Yampania at the Remote Sensing Institute, of Brookings (USA)

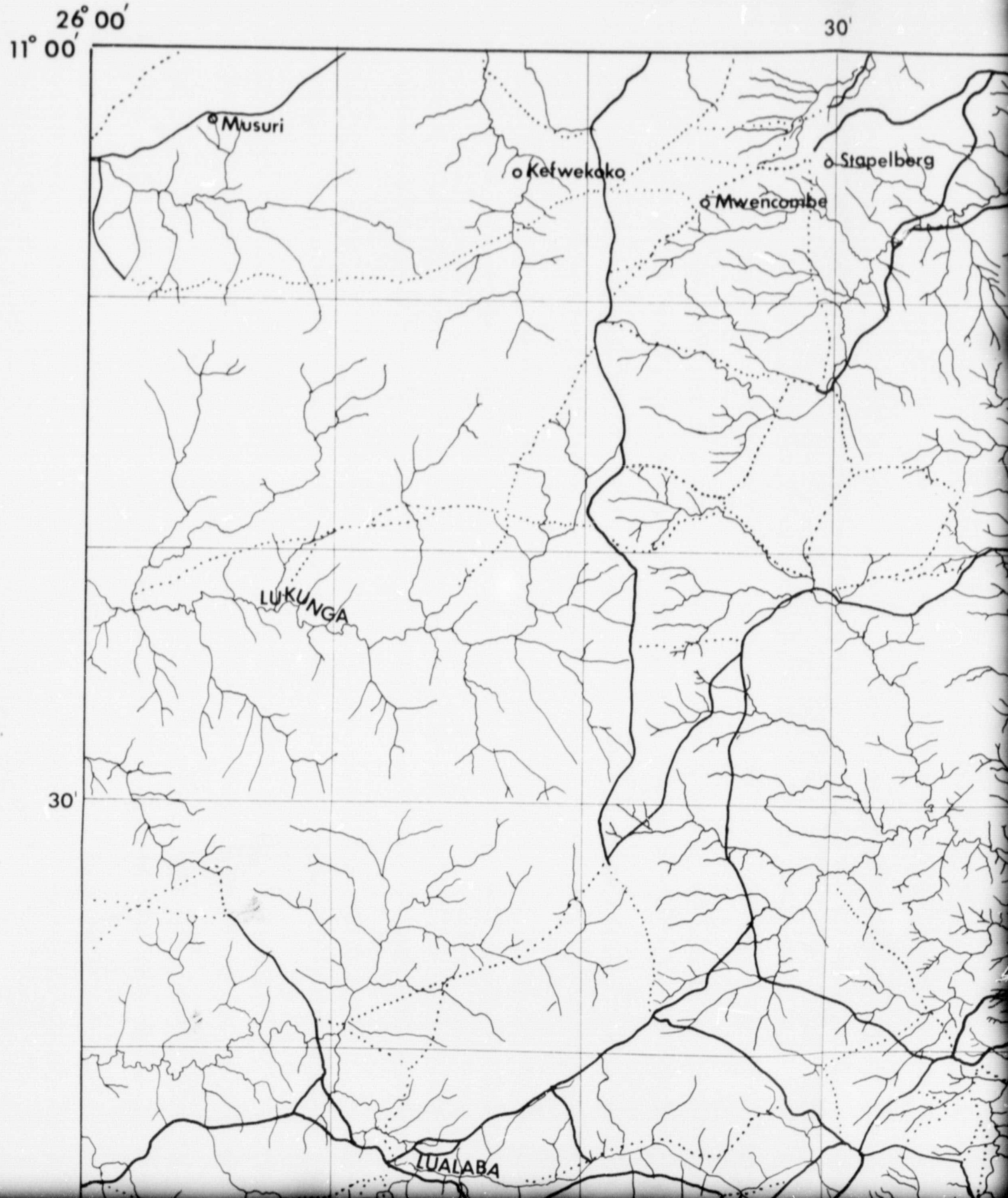
e interpretation of the region shown in Plate No. 3

ws the richness of details which can be taken from Landsat
s ground definition makes it possible to discern objects
ge dimension of 80 meters and sometimes less, because of
ast with its environment. The frame corresponding to this
ossible to trace the vegetation contour, swamp areas,
, watercourses, and several traces of highways.
as not sufficient contrast for determining these last
age did not give as much information as the map.

FOLDOUT FRAME

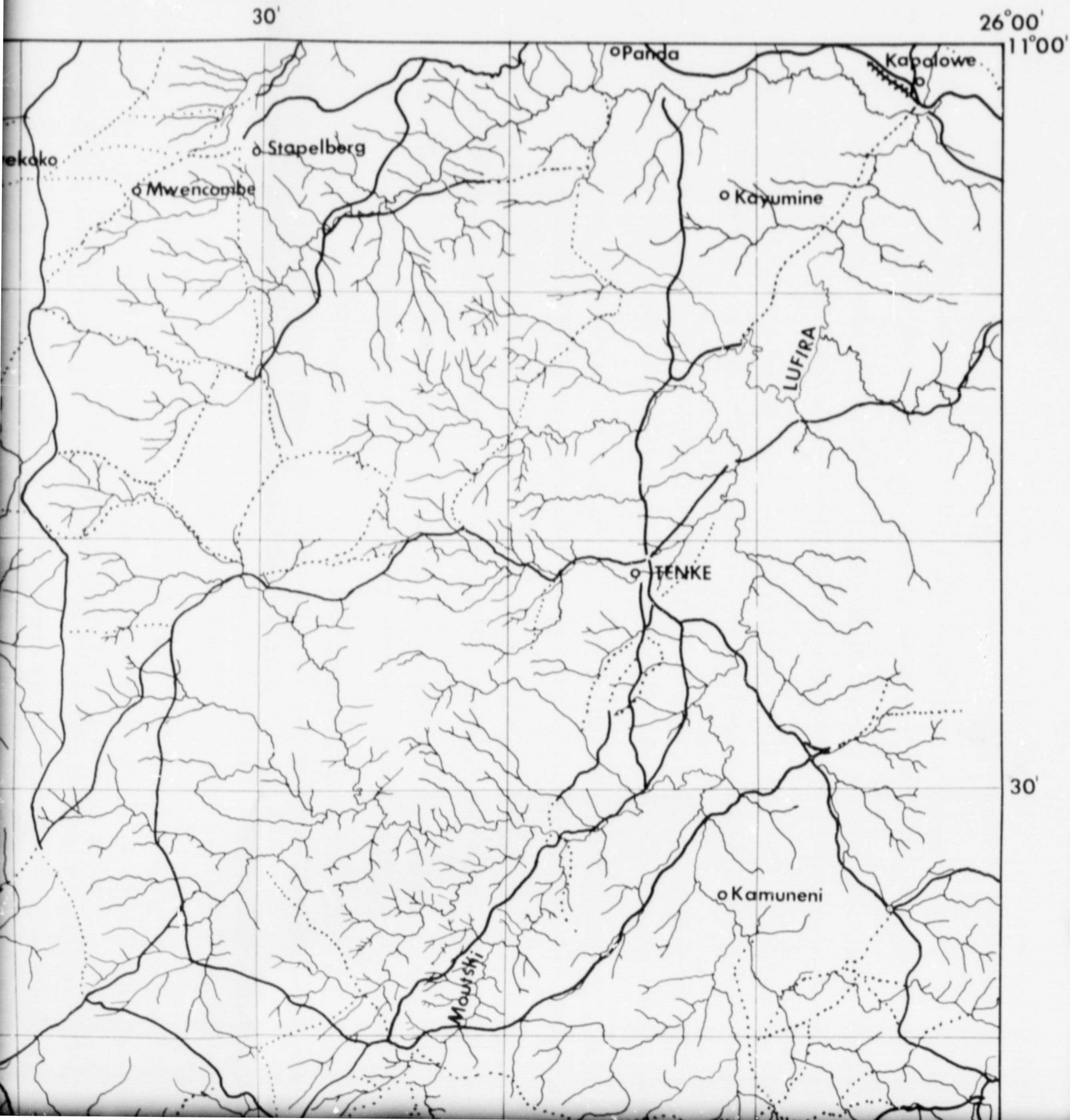
FOLDOUT FRAME

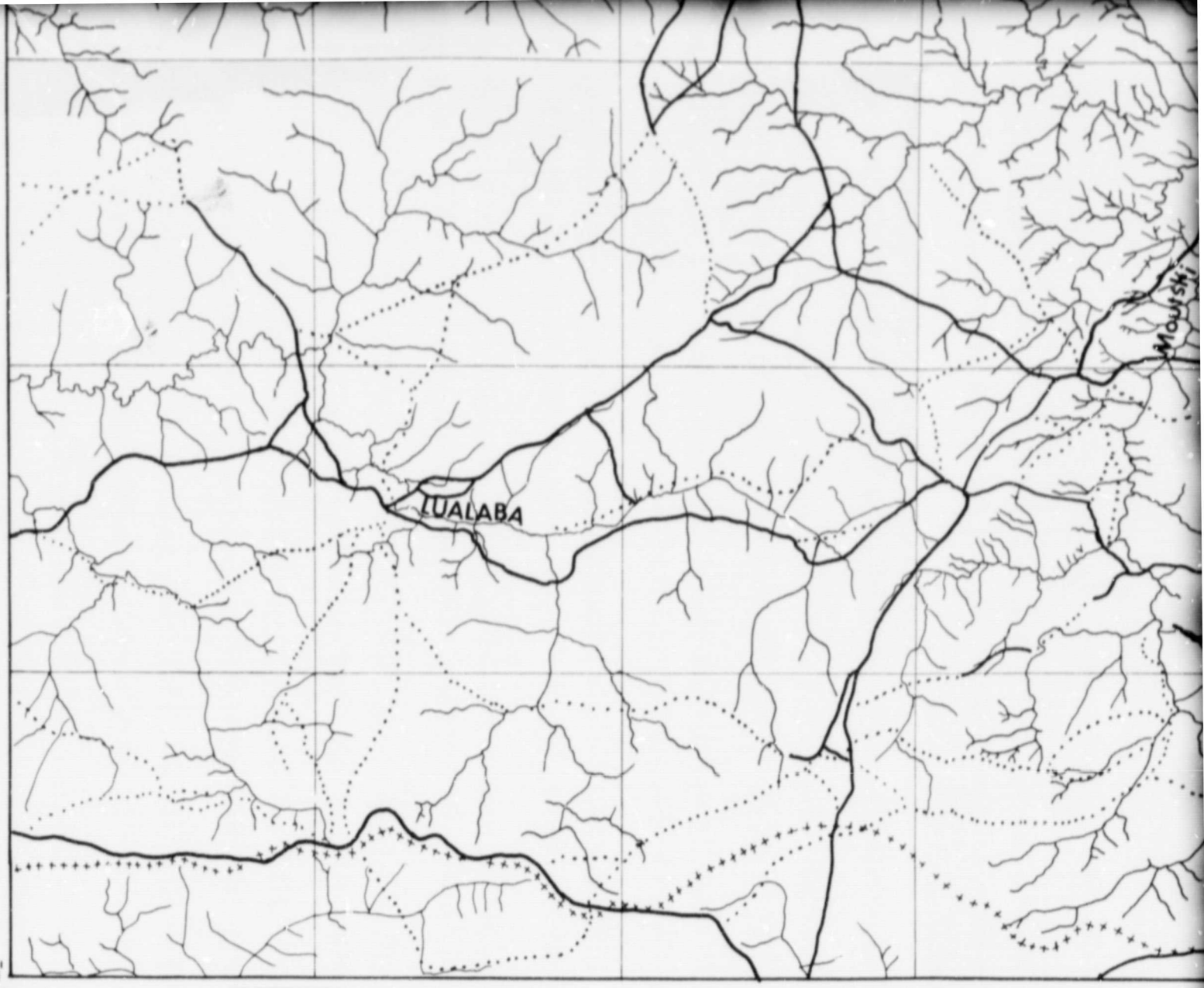
Plate No. 3: **TENKE**



FOLDOUT FRAME 2

Plate No. 3: **TENKE**





Legend

Zaire boundary

Road

Path

River

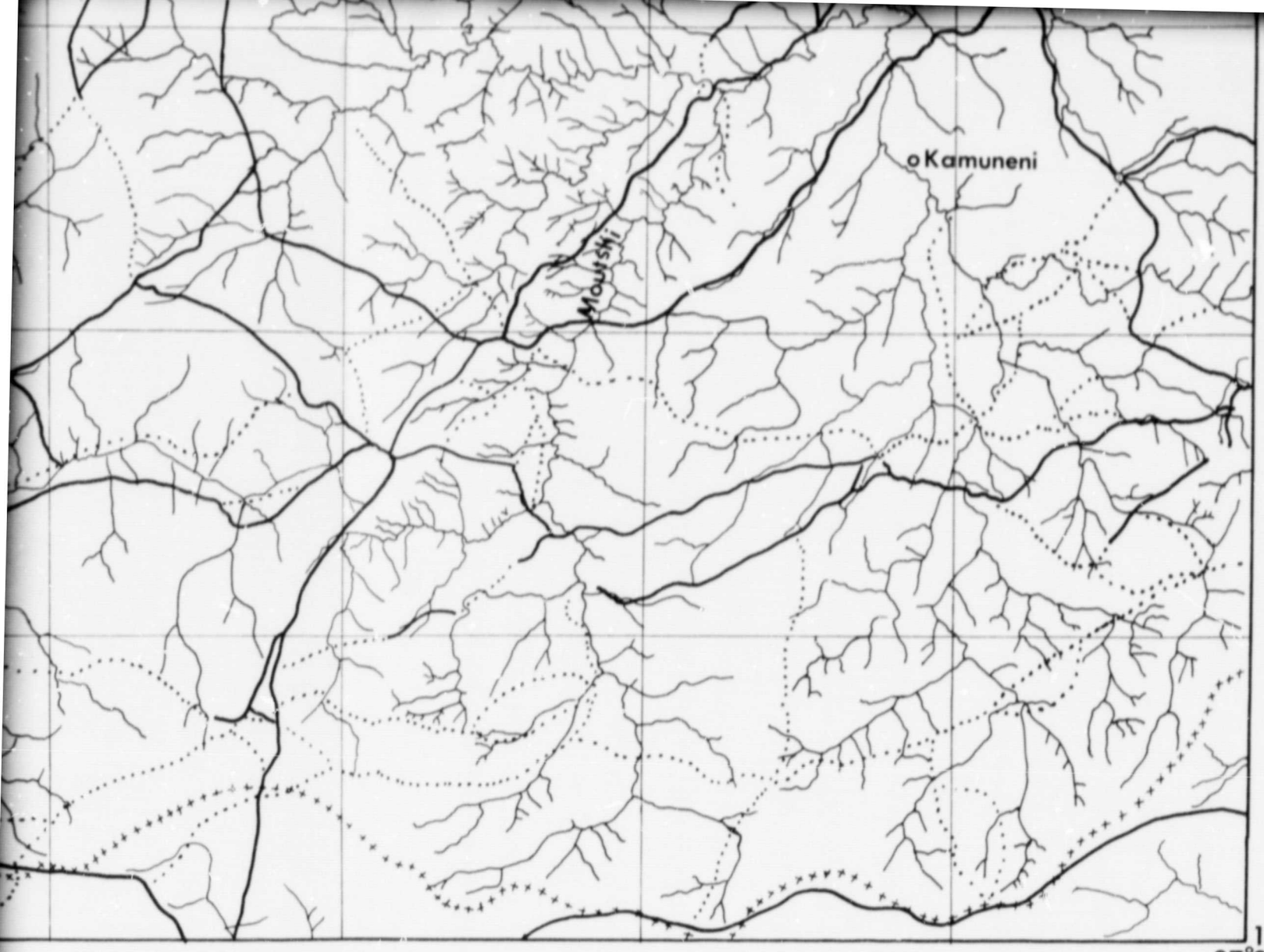
Inhabited zone

Railroad

0 5 10 15 30 K

The same region interpreted on the false color composite, Frame No. 1
August 4 1973 (See Plate No. 2)

FOLDOUT FRAME 3



0 5 10 15 30 KM

According to the
map of the Zaire Geographic Institute of 1929

The same region
on the false color composite, Frame No. 1377-07490 of
973 (See Plate No. 2)

FOLDOUT FRAME 4

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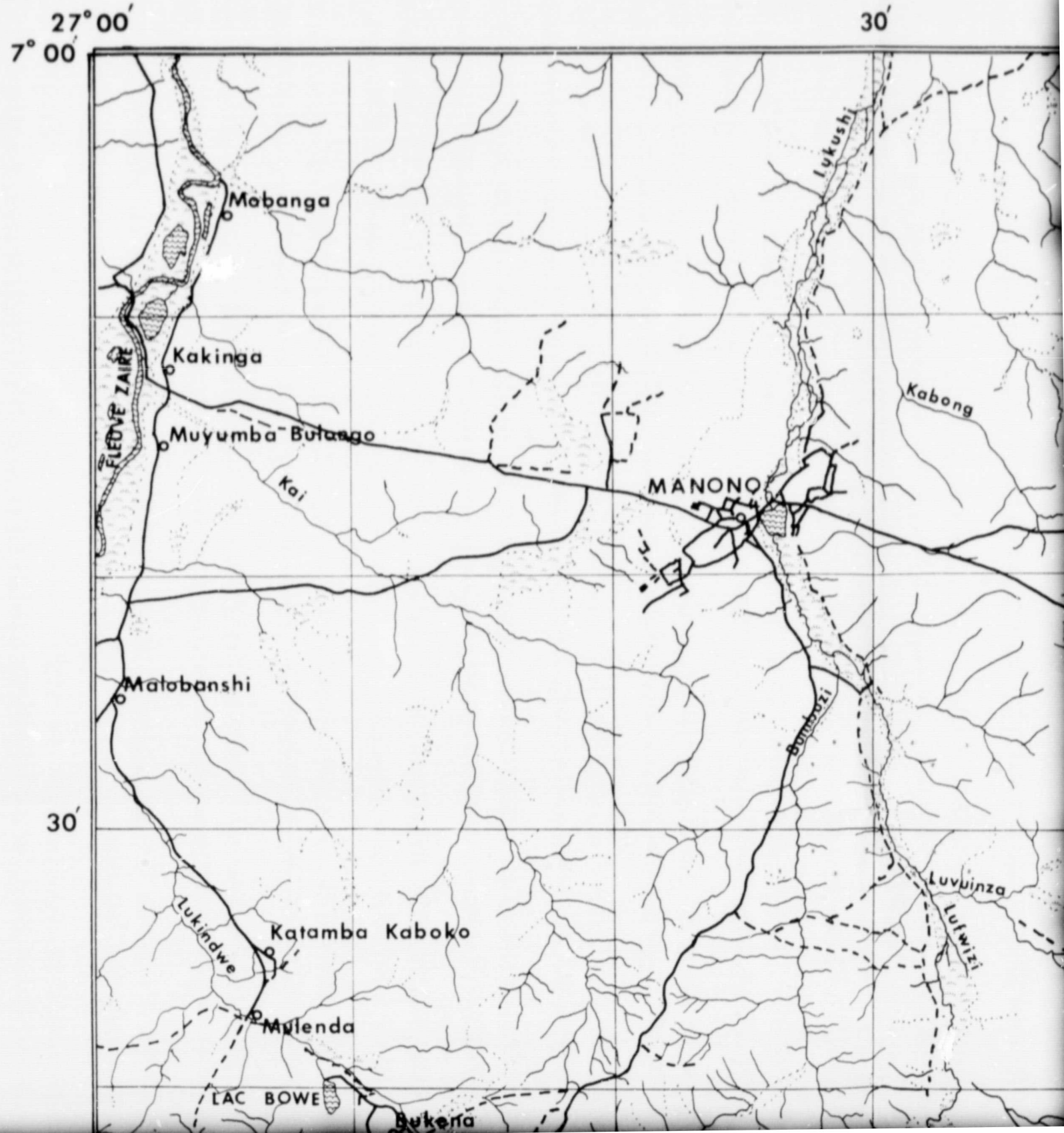
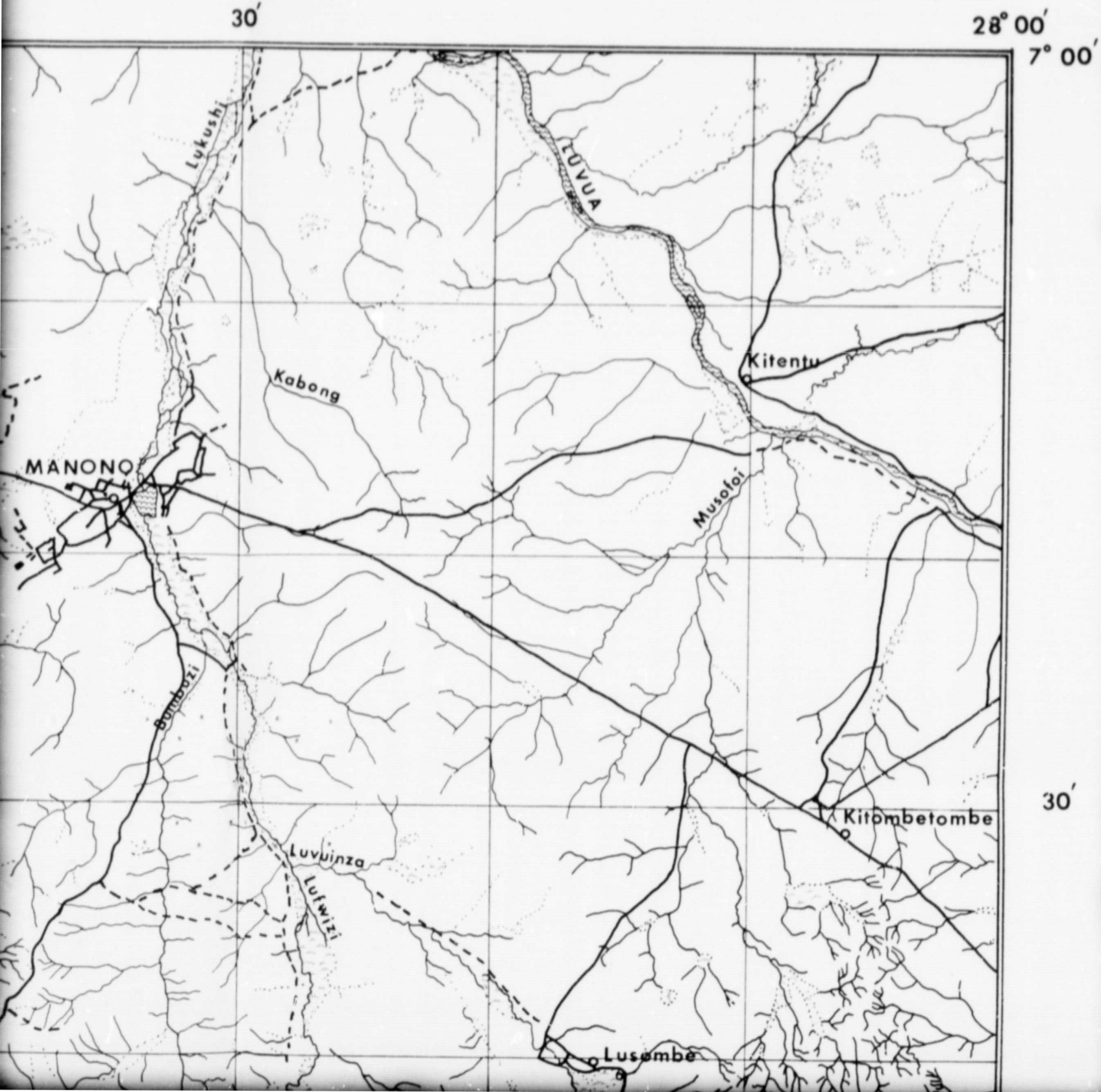
FOLDOUT FRAME

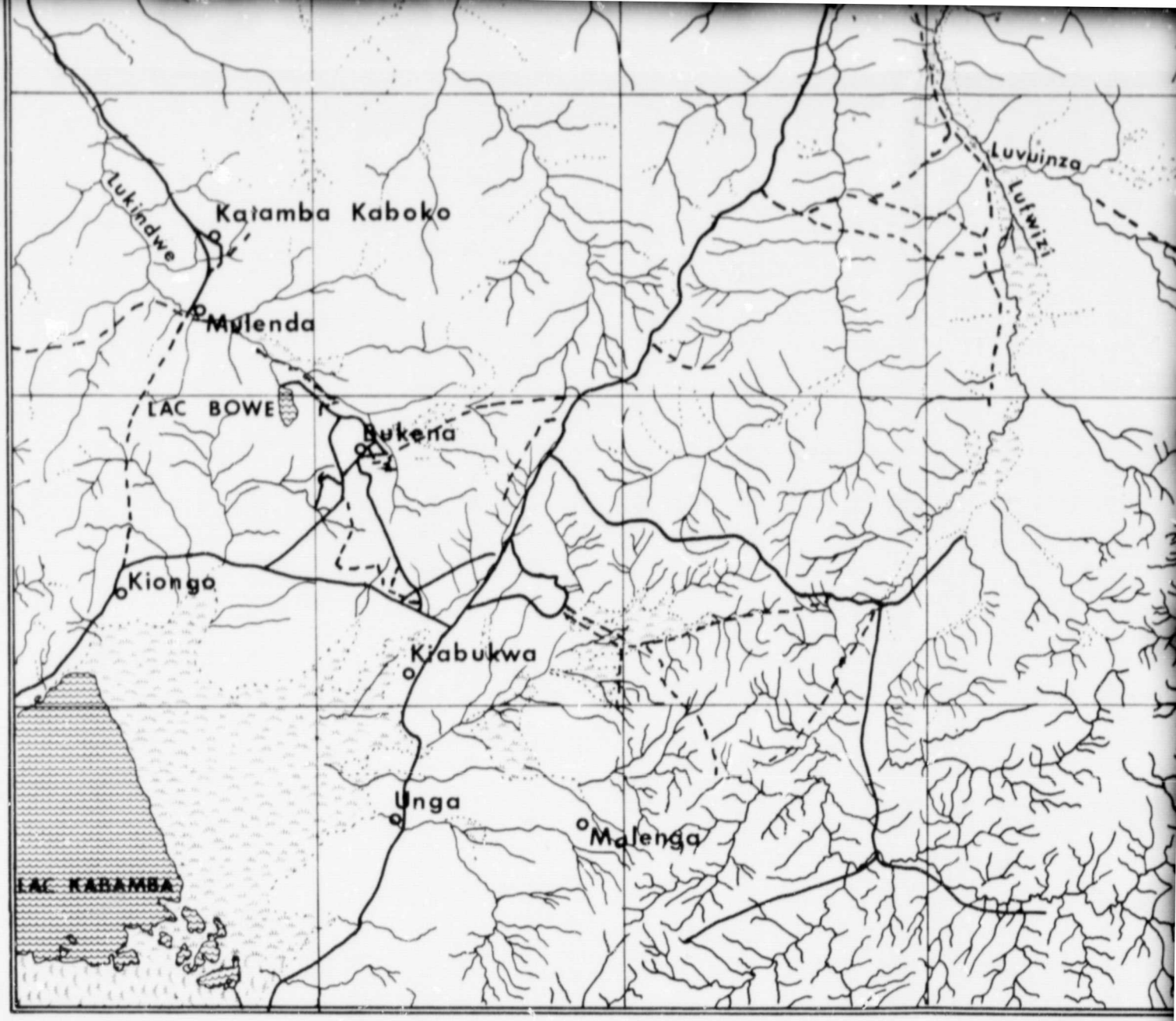
Plate No. 4: **MANONO**



FOLDOUT FRAME 2

Plate No. 4: MANONO



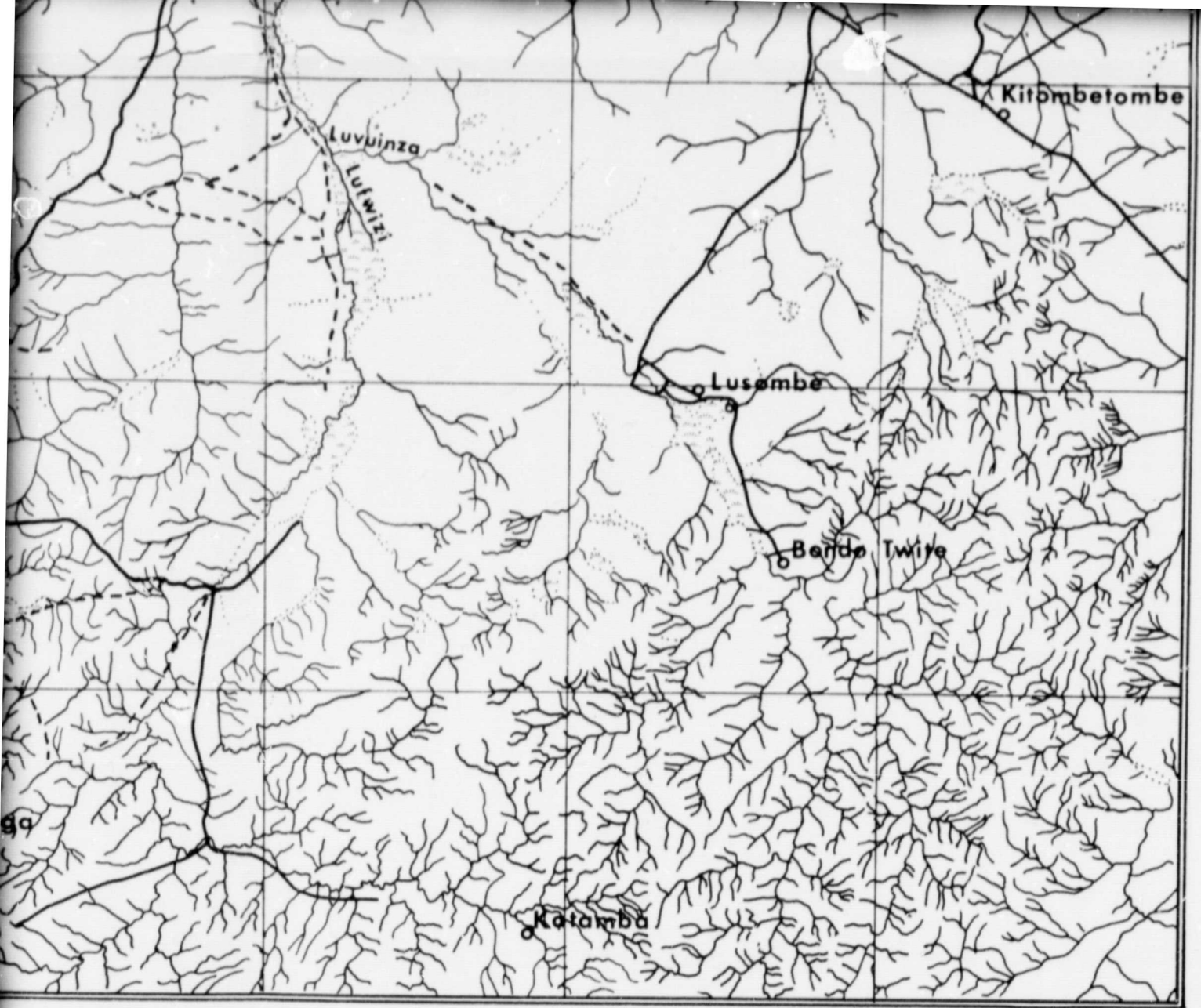


Legend

- Lake, large watercourse
- River
- Swamp
- Inhabited zone
- Road
- Path

The same region was interpreted on the RBV
of 4/07/1979 (See Plate No. 1)

FOLDOUT FRAME 3



ted zone

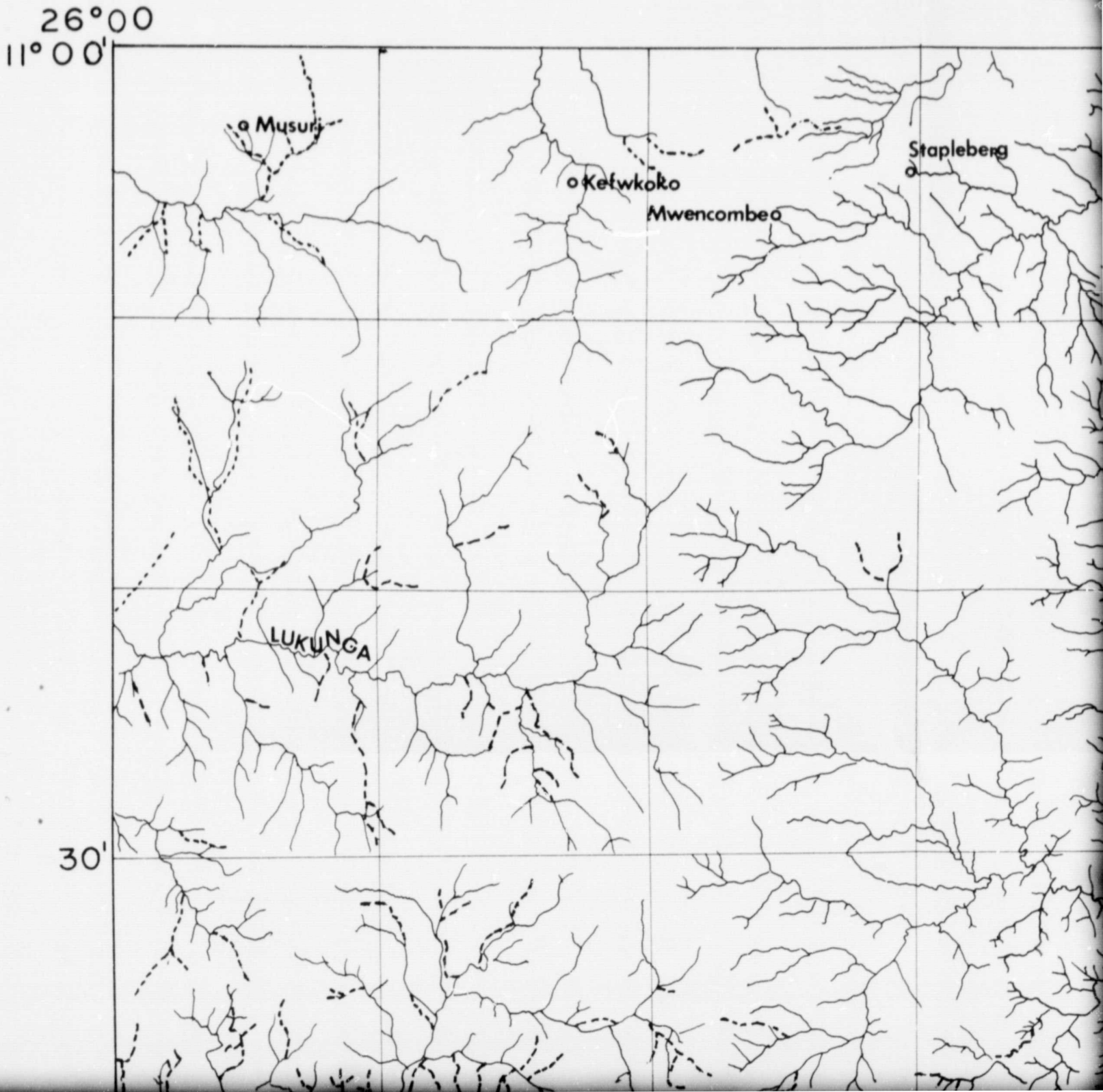
According to the Zaire Geographic Institute map of 1974 (the photographic coverage is from 1952).

region was interpreted on the RBV mosaic, Frame No. 30486-0760
(See Plate No. 1)

FOLDOUT FRAME 4

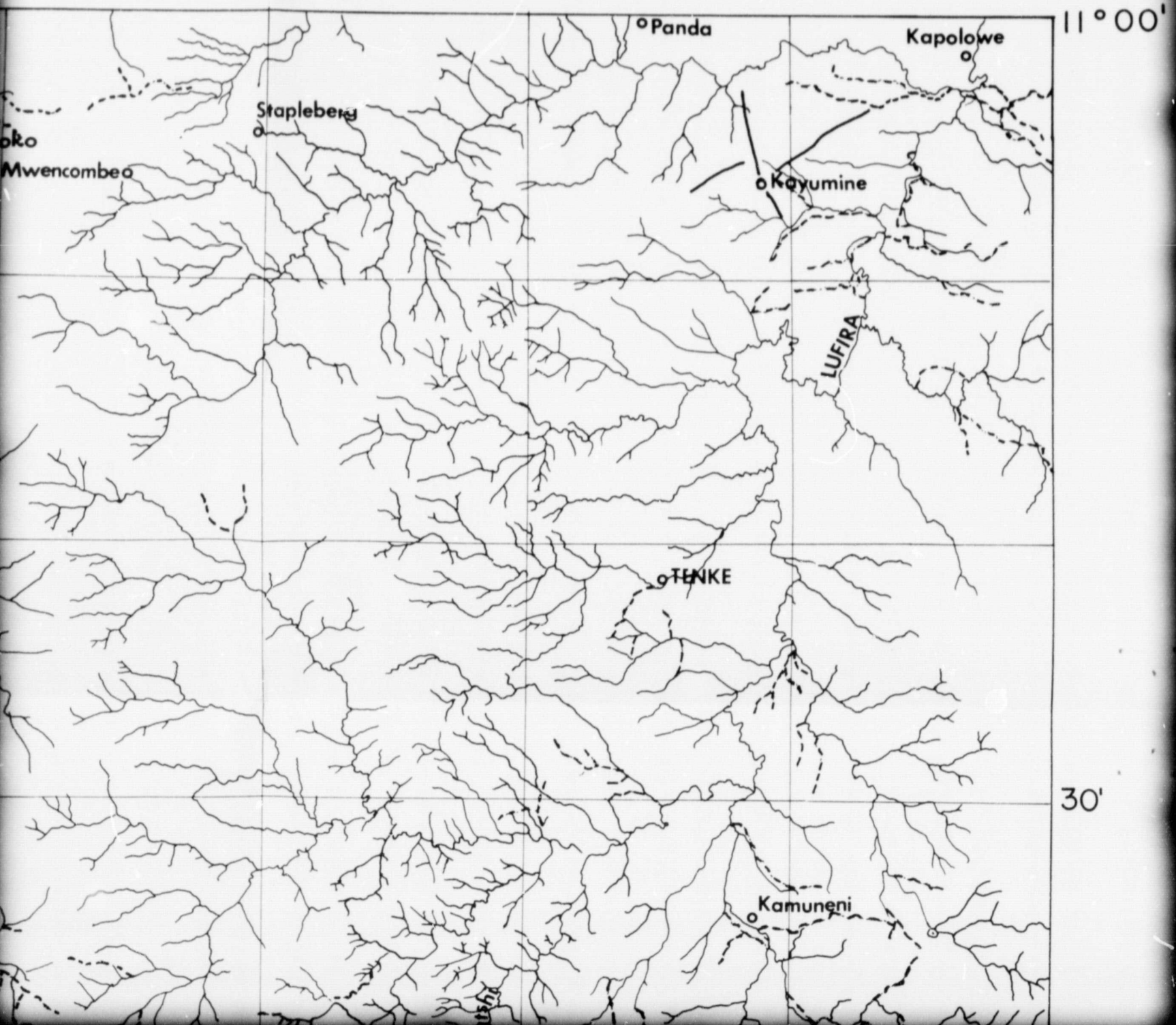
FOLDOUT FRAME

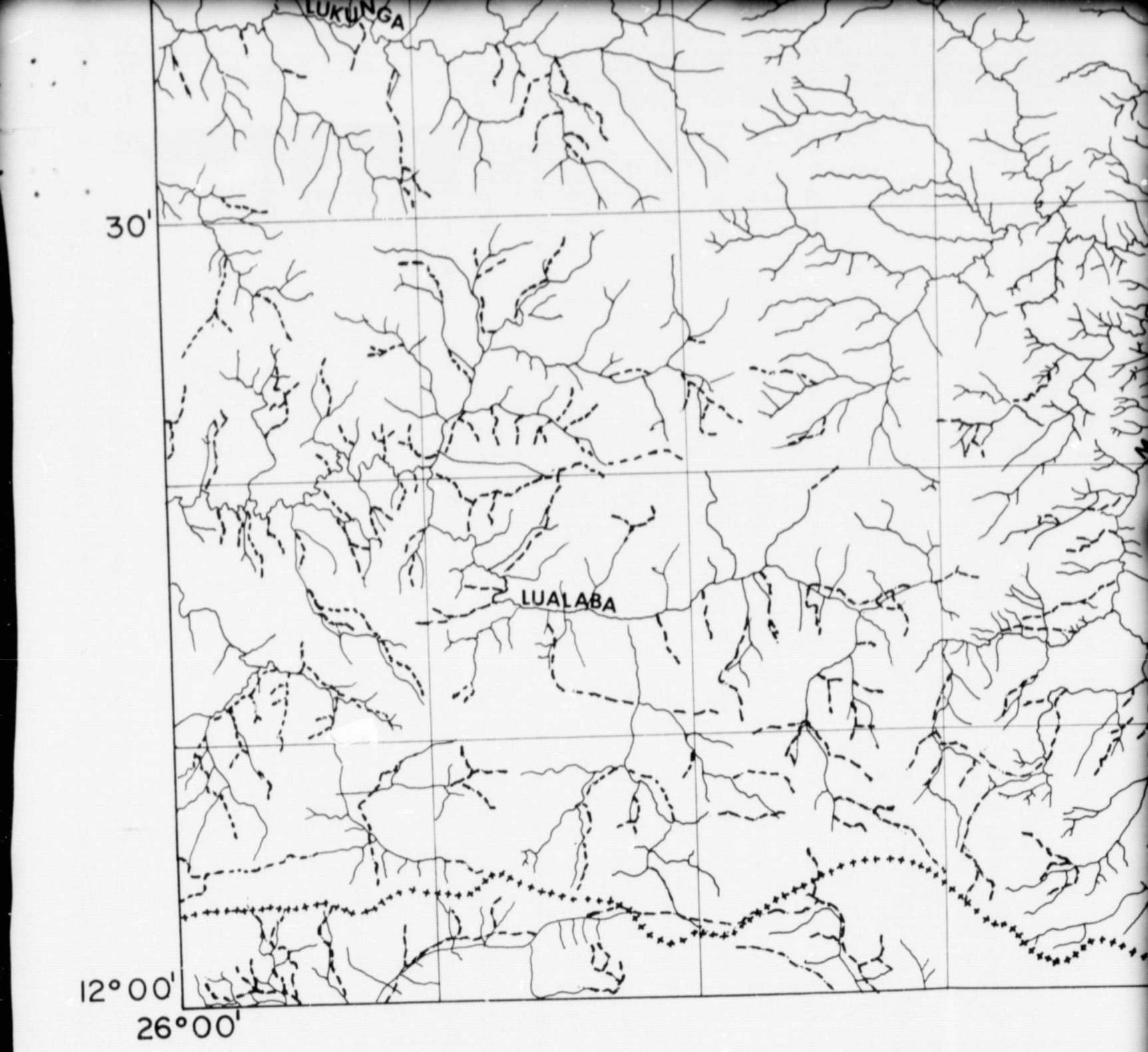
Plate No. 5: COMPARISON BETWEEN THE LANDSAT IMAGE AND



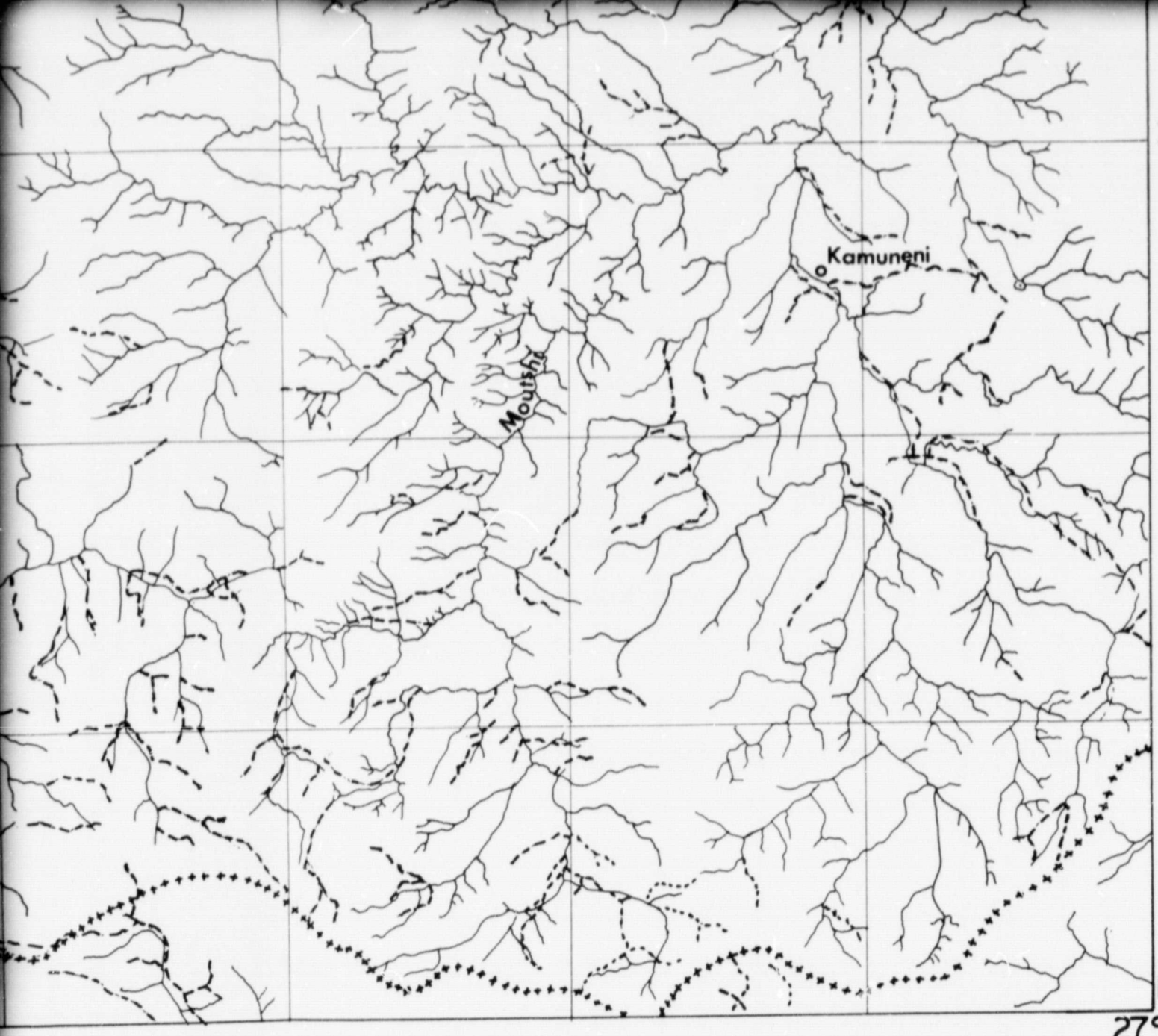
FOLDOUT FRAME 2

ARISON BETWEEN THE LANDSAT IMAGE AND THE TENKE MAP





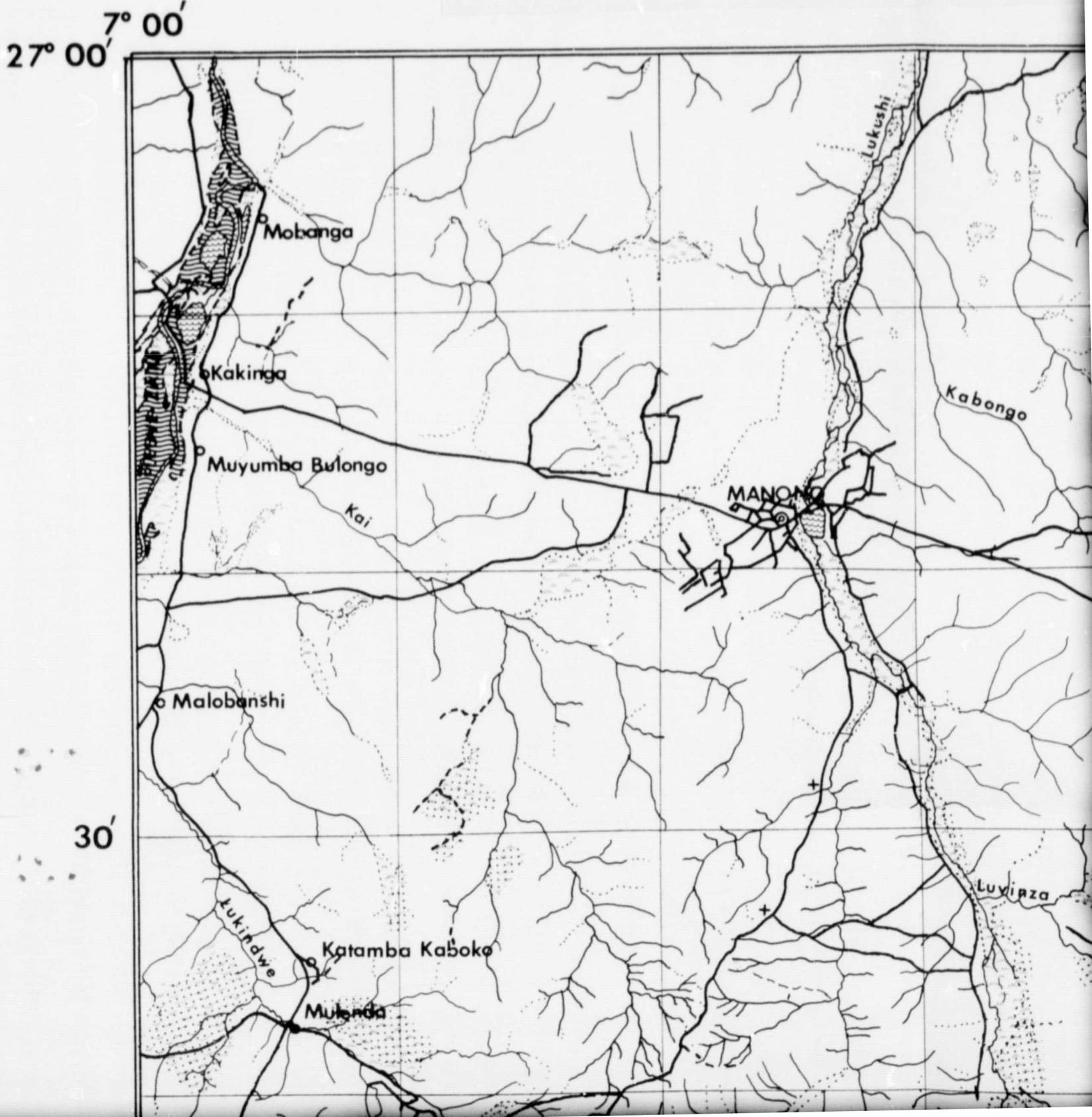
BOUNDARY PROBLEM
3



FOLDOUT FRAME 4

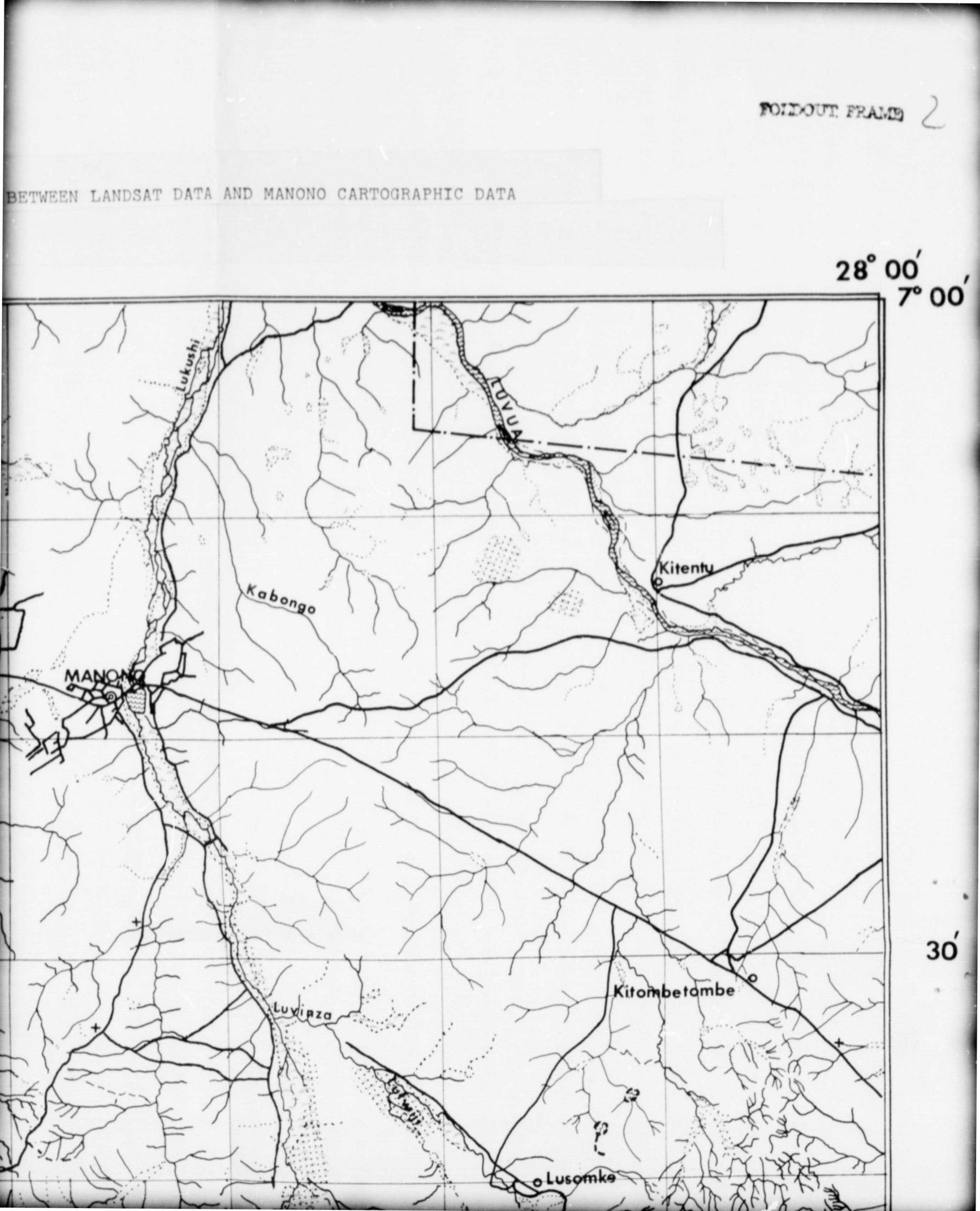
FOLDOUT FRAME

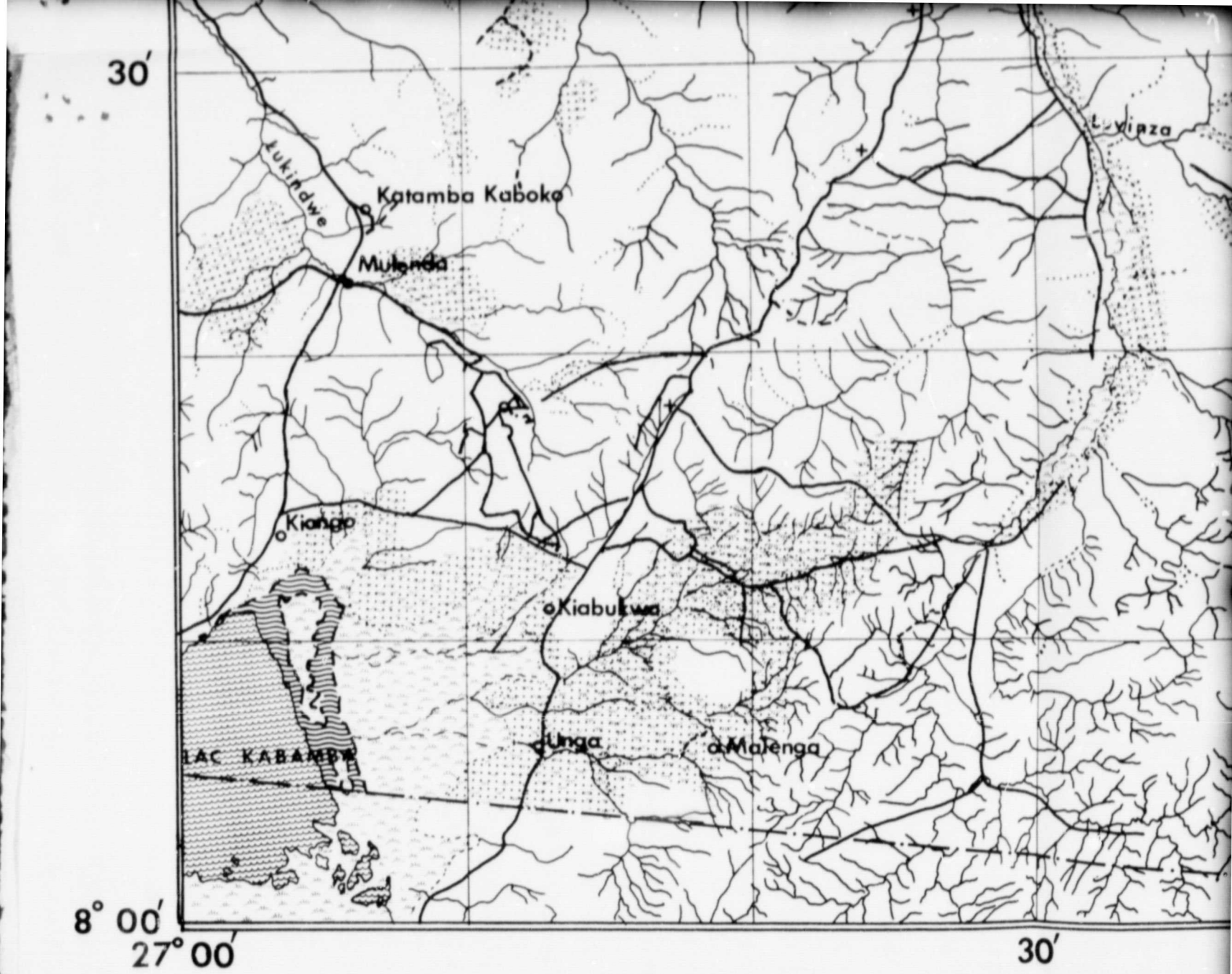
Plate No. 6: COMPARISON BETWEEN LANDSAT DATA AND MANONO CAR



FOLDOUT FRAME 2

BETWEEN LANDSAT DATA AND MANONO CARTOGRAPHIC DATA



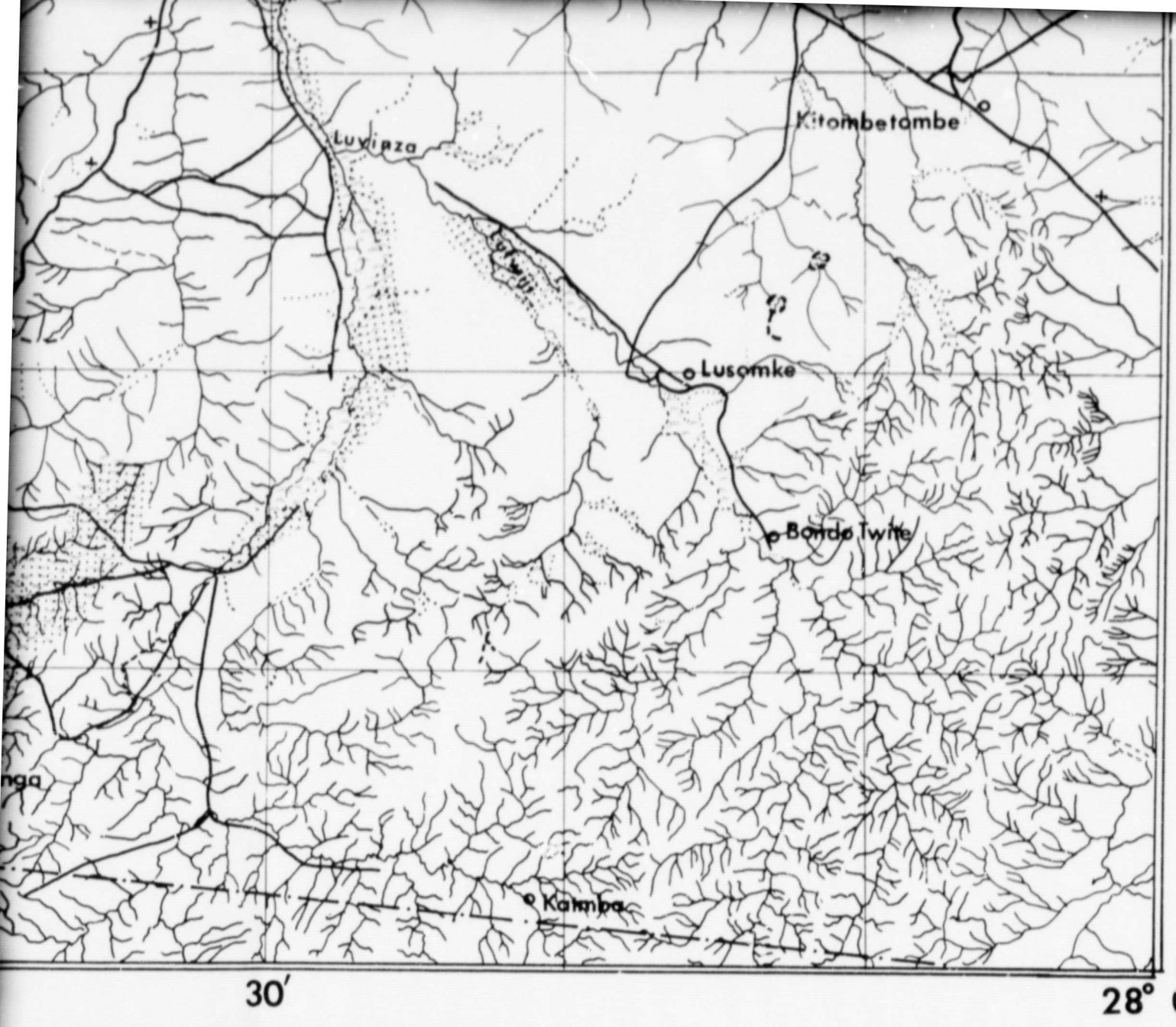


Legend

- Lake, large watercourse
- Extensive water area on the lake, river
- River (on Landsat and map)
- River (on Landsat but not on map)
- Swamp (on Landsat and the map)
- Swamp (on Landsat but not on map)
- Inhabited area (on Landsat and
- New inhabited area (on Landsat
- Road
- Mosaic boundary

0 5 10 15

FOLDOUT FRAME 3



BOLDOUT FRAME 4